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UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
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SAFETY CATCHES ON MINE CAGES AND METHODS OF TESTING THEM

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D. HARRINGTON AND J. H. EAST, JR.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SAFETY CATCHES ON MINE CAGES AND METHODS OF TESTING THEM[1]

By D. Harrington[2] and J. H. East, Jr.[3]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7436."

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INTRODUCTION

Shaft mines, coal and noncoal alike, have a common hoisting problem tha remains largely unsolved - how to obtain a mechanical device that will suspend a cage or skip in a mine shaft if the hoisting rope should break or become detached from the cage or skip and that will function effectively un all conditions of service. Safety catches, or safety dogs, as they are com monly named, are installed on nearly all mine cages and many skips operatin in American mines, but often, if the hoisting rope breaks, the cage or ski falls to the bottom of the shaft in spite of safety devices, causing much property damage and often fatalities.

Available information relative to safety catches for mine cages and sk desirable characteristics of safety catches, and methods of testing safety catches to determine whether they are functioning correctly has been assembl in this publication for the convenience of those responsible for the safe operation of mine cages and skips and, more particularly, to focus attentio on the need for a device that actually will stop and suspend a falling cage o skip under all conditions of use and do it without killing or maiming the occupants.

ACKNOWLEDGMENTS

The authors have used freely already published information gathered by engineers of the Bureau of Mines as well as information obtained from the report of the Ontario Mining Association Committee, which investigated the cage accident at the Paymaster Consolidated Mines, Ltd., and from various other sources. In fact, this publication is largely a compilation of information already published for the purpose of calling attention to some hoistin problems that have not yet been solved.

LAWS AND REGULATIONS GOVERNING SAFETY CATCHES ON MINE CAGES

The mining laws and regulations of most States relative to the use, testing, and inspection of safety catches on mine cages are inadequate; the State of Washington appears to have most specific laws in this respect. Som of the State laws and regulations with reference to safety catches on mine cages follow:

Washington

> Each cage must be equipped with efficient safety catches to prevent the cage from falling down the shaft in the event of the rope breaking***.
>
> The following tests of safety catches on cages shall be made once every 6 months. The cage shall be secured by passing a heavy hemp rope through the bridle chain ring or link and fastening both ends of the rope to guides or to diagonally opposite posts of head frame, drawing the rope taut. A blocking to be passed below the cage to support same before hoisting rope is taut. The hoisting

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> engineer shall then slack away until the cage is suspended on the hemp rope with at least 4 feet of the slack hoisting rope on top of it. Everything being in readiness the hemp rope shall be suddenly cut. If the safety catches stop the cage before it rests upon the blocking, the apparatus shall be considered efficient.

(Department of Labor and Industries, Coal Mining Laws of Washington, as amended 1919, 1927, 1939, and 1943: Secs. 62 and 64.)

Pennsylvania

The Pennsylvania bituminous mining law states, with regard to safety catches:

> ***and shall also provide for each said cage efficient safety catches, which shall be tested once every 2 months, and a record of each test shall be sent to the inspector and to the superintendent and also recorded with ink in a book kept at the mine office for that purpose.

(Pennsylvania Bituminous Mining Laws: Art. VIII, Sec. 1, 1940.)

The Pennsylvania anthracite law requires:

> ***efficient safety catches shall be attached to *** every cage used for lowering or hoisting persons in any shaft***. The ***safety catches***shall be examined carefully every day they are used, by a competent person delegated for that purpose, and any defects therein found by which life or limb may be endangered, shall be immediately remedied.

(Pennsylvania Anthracite Mining Laws: Secs. 10 and 13, 1941.)

Utah

The Utah Coal Mine Safety Orders state:

> The safety apparatus, whether consisting of eccentrics, spring, or other device, must be securely fastened to the cage and of sufficient strength to hold the cage loaded at any depth to which the shaft may be sunk***. Sufficient safety catches shall be attached to***and shall be provided on every cage used for lowering or hoisting persons in any shaft. The***safety catches***shall be carefully examined every day that they are used by a competent person and any defect therein found shall be immediately remedied.

(Industiral Commission of Utah, General Coal Mine Safety Orders.)

Chio

> The owner, lessee, or agent of a mine shall provide and maintain safe appliances, approved by the deputy inspector, for the ingress and egress of persons in each shaft***. The cages operated in said shaft shall have an approved safety catch***.

(Ohio Mining Laws: Secs. 898-59, 898-62, effective Sept. 2, 1941.)

Indiana

Approved safety catches shall be attached to every cage used for the purpose of hoisting and lowering persons.

(Indiana Mining Laws: Sec. 3523.)

Idaho

***to a greater depth than 250 feet without having the same equipped with a mine cage, skip or bucket fitted with safety clutches.

(Mining Laws of the State of Idaho, Sec. 46-409, 1937.)

California

***in vertical shafts over 50 feet in depth shall be covered by an iron bonnet, shall travel in guides, and shall have safety dogs that will hold the fully loaded cage, skip or bucket should the hoisting rope fail.

(Mine Safety Orders, Industrial Accident Commission, State of California. Order 1733 (a), 1938.)

Montana

***The safety apparatus, whether consisting of eccentrics, springs, or other device, must be securely fastened to the cage and of sufficient strength to hold the cage loaded at any depth to which the shaft may be sunk.

(Laws of Montana, Industrial Accident Board, Sec. 3427, 1935.)

Arizona

***and every cage or skip used for hoisting men shall be provided with a safety catch of sufficient strength to hold the cage or skip with its maximum load at any point in the shaft in the event the hoisting cable should break. The inspector shall see that all cages and skips are equipped as herein required, and that on all cages the safety catches are kept well oiled and in good working condition.

(Mining Code of the State of Arizona, Sec. 2293.)

Wisconsin

(c) Sides, Gates, and Safety Catches.

***Every cage shall be provided with safety catches of sufficient strength to hold the cage with its maximum load at any point in the event the hoisting cable should break.

(d) Testing Safety Catches.

> The safety catches of cages and skips used to hoist men shall be kept well oiled and in good working order. They shall be tested at least once each month by tying up the cage or skip with hemp rope, lowering a few feet of hoisting cable on top of cage, then cutting the hemp rope, provided that any other system of testing, which is equally effective, may be used.

(General Orders on Mines, Industrial Commission of Wisconsin, Order 316 - Cages for Hoisting Men, 1937.)

GENERAL

Safety in mine hoisting is given considerable attention at most mines; usually the cages and skips are kept in good mechanical condition, the shaft guides are inspected and repaired, the attachments that suspend the cage or skip from the hoisting rope are inspected regularly, the ends of the hoisting rope are cut off at intervals and reattached to the fittings, the hoisting rope is inspected and changed when it shows a dangerous amount of wear, and the safety catches are tested periodically to be sure they function correctly. However, hoisting ropes continue to break and cages or skips continue to fall to the bottom of the shaft, usually killing or maiming every one on the cage and causing heavy property damage as well as loss of production through interruption of the hoisting facilities.

The safety catches probably function in many instances to stop the cage or skip from falling, but far too frequently the safety device is unable to stop and suspend the cage or skip. The instances when the safety catches succeed in suspending the falling cage or skip are not publicized and few people outside the mine locality know about them. The instances when safety catches are unable to stop the cage or skip and a major accident, with loss of life or heavy damage to property, occurs are given publicity and serve to focus the attention of the mining world on the need for a positive device to prevent such accidents. The most recent major disaster from this cause occurred at the Paymaster Consolidated Mines, Ltd., in Ontario, Canada, on February 2, 1945, causing the death of 16 men.

Safety catches or safety dogs usually act with sufficient effectiveness to suspend a cage or skip if it is ascending when the hoisting rope breaks, or when the cage or skip becomes detached from the rope somehow, as the cage or skip must stop momentarily before it starts to fall. However, if the hoisting rope breaks while the cage or skip is descending, its momentum and the heavy weight of the rope below the break falling on the cage place a terrific burden upon safety catches; frequently the guides are torn out, and often spaces between the teeth of the safety catches become filled with wood, causing them to cease to function.

Obviously, a device is needed by the mining industry that can stop and suspend a falling cage or skip under all conditions of use, as well as a method of determining when a hoisting cable is weakened dangerously and should be removed from service. Until these problems are solved, persons who are required in their work to travel in mine cages must continue to be subject to these hazards.

FALLING-CAGE ACCIDENTS

Statistics relative to falling-cage accidents in the United States are not available; few if any records are kept by the individual States and no national records are kept. Accounts of such accidents in which loss of life occurred are recorded in some of the Bureau of Mines publications and State records, but they are known to be incomplete.

The committee investigating the falling-cage accident at the Paymaster Consolidated Mines, Ltd., listed 47 accidents of this type in Ontario, showing the primary cause of the accident and the distance from the conveyance at which the rope broke. Not all of these accidents involved personal injuries or fatalities, but all of them caused considerable property damage and loss of production.

The mining methods and equipment used in Ontario mines closely resemble methods and equipment used in similar mines in the United States, and it appears reasonable to assume that the statistics assembled in Ontario represent in a general way what occurs as a result of mining conditions and procedures in the United States.

Table 1 lists the Ontario falling-cage accidents, showing the year, cause of accident, and distance of the break in the hoisting rope from the conveyance.

TABLE 1. - Falling-cage accidents in Ontario

Year	Cause of accident	Distance of break from conveyance, feet	Remarks
1925	Socket failure	0	
1925	do.	0	
1926	Brakes failed	1 at drum, 1 at skip	Both ropes broke.
1929	Skip struck pier	21	Inclined shaft.
1930	Overwind	0.2	
1930-31	Unsuitable rope	500	
1933	Skip jammed	Close to skip	Inclined shaft.
1935	Corroded, brittle rope	70	
1935	Frozen sheave	1,500	Broke at sheave.
1936	Weak rope	30	
1937	Skip jammed	0	Inclined shaft.
1937	Frozen counterbalance	Not reported	
1937	Slack rope	200	Skip caught in tipple
1937	Overwind	Short distance	

TABLE 1. - Falling-cage accidents in Ontario (Cont'd.)

Year	Cause of accident	Distance of break from conveyance, feet	Remarks
1938	Kinked rope	Few feet	Bailer.
1938	Overwind	0	
1938	Sheave axle broke	350	
1938	Corrosion	127	
1939	Overwind	0	Limit switch froze.
1939	Kinked rope	200	Skip stuck in dump.
1939	Overwind	1	
1939	Overwind into sheave	0	
1940	Corrosion	250	
1940	Weak rope	165	
1940	Corrosion	2,050	
1940	Load fouled	130	
1940	Overwind	0	
1940	do.	0	
1940	Weak rope	700	
1941	Crosshead frozen to rope	12	
1941	Skip axle broke	120	Inclined shaft.
1941	Cage froze to guides	0	Slack rope.
1941	Sheave broke	625	
1942	Worn rope	950	
1942	Skip fouled	31	
1942	Overwind	100	
1942	Hoist clutch failed	2,600	
1943	Hoist brake failed to hold	4,000	Broke at spout.
1943	Faulty braking	200	
1943	Skip jammed	73	
1943	Corrosion	108	
1943	do.	1,738	
1944	Faulty braking	30	
1945	Kinked rope	235	
1945	Overwind	0	
1945	Corrosion	1,130	

It is probable that the accidents shown in table 1 do not include all of the falling-cage accidents that have occurred in Ontario mines during the period of time shown in the table, particularly in the earlier years, but there are enough to establish the major causes of this type of accident. The regularity with which cages or skips fall owing to a broken hoisting rope or to mechanical failures, serves to emphasize the importance of installing safety catches on shaft conveyances that will stop and suspend them under all conditions of use.

The 47 Ontario accidents are classified by causes, as shown in table 2, and it is noticeable that socket failure occurred in only 2 of the 47, this cause usually being the one suspected of being troublesome.

TABLE 2. - Causes of falling-cage accidents in Ontario

Number of accidents	Cause of hoisting rope breaking	Percent of total
11	Overwind........................	23.4
7	Corrosion........................	14.9
6	Faulty operation of hoist........	12.8
6	Skip jammed or fouled............	12.8
5	Weak or worn hoisting rope.......	10.6
3	Failure of hoist brake or clutch.	6.4
5	Failure of other equipment.......	10.6
4	Weather..........................	8.5
47		100.0

SOME CAUSES OF HOISTING-ROPE FAILURES

The lack of a positive safety device that will stop a falling cage or skip consistently in case of breakage of the hoisting rope makes the cause of hoisting rope failures of extreme importance. Manufacturers of wire rope have issued much valuable information regarding proper handling and storing of wire rope and the danger of incorrect installations. Some information on this subject is available in Miners Circular 61, Safe Practices in Mine Hoisting, published by the Bureau of Mines.[4]

Among the common causes of hoisting-rope failure that have not received the publicity they deserve are the following:

Hoist Drum Size and Multiple Layers of Rope on the Drum

The life of a hoisting rope is lengthened and the probability of its failing is lessened by the use of hoist drums of relatively large diameter, thereby avoiding more than two layers of rope on the drum. The size of a hoist drum in relation to the diameter of the hoisting rope is not standardized; frequently a small hoist is used, for economic reasons, where a larger one is needed, and it is not uncommon to see hoist drums wound with six or seven layers of rope when the cage is at the collar of the shaft.

It is well-established that hoist drums should be of relatively large diameter to avoid bending stresses in the wire rope. Tests have shown that bending stresses are of negligible value when the ratio of drum diameter to rope diameter is 120; a British Wire Rope Research Committee found that a ratio of 60 to 1 led to complete fracture of a typical regular-lay rope at 500,000 bends. The committee investigating the Paymaster Consolidated Mines Co. falling-cage accident recommended that "strong efforts should be made to attain a ratio of 80 to 100 in future installations and modifications of existing ones. Not only would it keep the bending stresses moderate, but it would also obviate the objectionable piling up of many layers of rope on the drum.

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[4] Harrington, D., and East, J. H., Jr., Safe Practices in Mine Hoisting; Bureau of Mines Miners Circular 61, 1946, 55 pp.

Drum Grooving

Helical grooving of the surface of a drum lessens rope wear, but grooving in planes parallel to the drum flanges (so-called parallel grooving) is not satisfactory, as the hoisting rope must climb over the ridges between adjacent grooves, and the rope is almost certainly to be damaged.

Plain ungrooved hoist drums sometimes become grooved by rope slippage; some of the wear occurs when the rope is worn, hence the grooves are smaller in diameter than a new hoist rope that replaces the worn one, and this manifestly is detrimental to the new rope. The grooves worn in the hoist drum by the rope should be removed if the life of a new rope is to be what it could or should be.

Fleet Angle[5]

If the fleet angle is excessive, the rope will slap abnormally at the drum end and will receive excessive wear between wraps at the extreme ends of the drum. Frequently the rope, after climbing on the preceding wrap, will jump over into the second valley between the coils, and the next wrap will fall into the gap, causing excessive wear. It is necessary to cut off longer lengths from the drum end of the rope when this occurs in order to change the position of the rope crossover. The maximum fleet angle recommended is 1½ degrees on a smooth drum.[6]

Head Sheaves

Experimental investigations have shown that, other things being equal, the larger the diameter of a head sheave, the greater the endurance of the hoisting rope. The sheaves should be well-balanced, as light as is compatible with strength to reduce inertia in starting and stopping, and free-running, as lack of this last causes scrubbing or scraping, which wears the rope.

The desirable ratio of the diameter of the head sheave to the diameter of the hoisting rope has been established by the American Standards Association; many of the wire-rope manufacturers have published recommended average and minimum sheave diameters. These ratios are given in table 3.

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[5] The fleet angle may be defined as the included angle between the rope, in its position of greatest travel across the drum, and a line drawn normal to the drum shaft passing through the center line of the head sheave or the lead-sheave groove.

[6] American Steel & Wire Co., Wire Rope Engineering Handbook: New York, N.Y., p. 68.

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TABLE 3. - Ratio of sheave or drum diameter to diameter of hoisting rope

Rope construction	American Standards Association	Wire rope manufacturer[7]	
		Average	Minimum
6 by 7...............	96	72	42
6 by 19..............	60	45	30
8 by 19..............	30	31	21
6 by 37..............	30	27	18

The same rope manufacturer[7] states "On large hoisting installations using 6 by 19 rope, the head sheaves are sometimes set as high as 90 times th rope diameter. On installations of this type it has been found that considerable fatiguing action takes place with sheaves of 72 times the diameter of the hoisting rope; also, that this action is materially reduced when the sheaves are increased to 80 times the rope diameter, and the fatiguing actio is practically eliminated when the sheaves are set at 90 times the rope dia- eter."

Worn sheave bearings permit the sheave to wobble and produce rope vibrations. Bad alinement may cause rope and sheave wear; broken flanges are a great source of danger to hoisting ropes. A sheave with a broken flange sho be removed from service as soon as feasible.

THE WEAKEST SECTION OF A HOISTING ROPE

The section of a hoisting rope that is most likely to break has been th subject of much discussion among mining people, and considerable informatio as to the results of investigations of this subject has been published in th foreign technical magazines, particularly in relation to the deep mines in South Africa. Investigations have been made, but the results are not conclusive; however, they tend to disprove the commonly accepted belief that a hoisting rope is most likely to break at or near the socket or point of atta ment on the end of the rope next to the cage or skip. The Ontario Departme of Mines conducted investigations on hoisting-rope failures but were unable determine definitely which section of the rope is weakest, although only 2 o of 47 accidents studied were ascribed to socket failure.

The record of failures of hoisting ropes at Ontario mines (table 1) sho that failure occurred in the 6-foot length of rope immediately above the sha conveyance in only 17 instances, or 35 percent of the total failures recorde hence, routine tests of sections cut from the socket end of the rope would n have disclosed the weakness that existed in 65 percent of the cases.

The Ontario Department of Mines tested sections of 44 hoisting ropes discarded over a period of several years, and the results of the tests show that weak sections may occur at almost any point along the portion of the r hanging in the shaft. The tests showed that the weak section of the rope w not at or near the socket or point of attachment in 41 of 44 ropes investig

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[7] John A. Roebling's Sons Co., Wire Engineering: 1941, 152 pp.

In only 15 percent of the tests was the weak section found in the lowest 10 percent of the rope length between the sheave and the socket when the cage was at the bottom of the shaft.

The investigators found that out of 163 hoisting ropes from which the end section had been cut off for resocketing, 27 were replaced by reason of discovery of deterioration close to the socket (called capel in Great Britain); this is 17 percent of the total cases investigated. They also found that of 85 hoisting ropes that broke in service, 22 percent broke at or within 10 feet of the socket for reasons other than faulty socketing.

Internal deterioration was found more usual in those parts of the rope that lie between the rope socket and the hoist drum when the cage is at the collar of the shaft, or between the sheave and the hoist drum when the cage is at the bottom of the shaft. These are the portions of the hoisting rope that are exposed to the weather for the longest periods, as generally the shaft conveyances are stationary more often than they are moving. The critical condition of dryness and dustiness throughout the cross section of the rope, with severe internal corrosion, was found at the socket only about one-third as often as it was found elsewhere.

It is obvious that the point where a hoisting rope is most likely to break was not established by the tests, but the results show conclusively the necessity of close inspection of the entire hoisting rope, and not merely the socket end of the rope where it is attached to the cage or skip, as is usually done.

INTERNAL CORROSION

The dangerous results of internal corrosion of a wire rope are seldom realized, yet internal corrosion undoubtedly is one of the principal reasons for hoisting-rope failures. In the Ontario list of falling-cage accidents shown in table 1, internal corrosion of the hoisting rope was held to be the cause of 14.9 percent of the total number recorded and was exceeded only by "overwind", which obviously was not the fault of the rope.

Internal corrosion is found in ropes that show little, if any, effects of wear on the outside of the rope, yet the internal wires may be nearly completely destroyed by corrosion. High resistance to corrosion is a primary requisite for hoisting ropes, and anything that tends to promote corrosion is likely to be more dangerous than something that produces surface wear, as the latter can be detected easily.

It is important to realize that the steel of wire rope will corrode in pure water when oxygen is present; hence, deterioration from corrosion is not confined to operations having acid-bearing water or salts in solution. The conditions that exist in many mine shafts are ideal for corrosion, i.e., high humidity, free water, acids, mud, and temperature fluctuations. The complete enclosure of the hoisting rope between the hoist house and shaft house does not eliminate corrosion, because almost invariably shaft conditions favor corrosion.

Deterioration in a wire rope produced by a combination of corrosion and fatigue, known as "corrosion fatigue," may be much more severe than that due to either one acting alone. Fatigue is likely to be revealed by cracked or broken wires, whereas corrosion takes place between the strands, with the result that the rope's strength may be less than one-third of the original strength without external evidence thereof. This was determined to be so at the Paymaster accident.

Reverse bending of the wire rope, particularly when corrosion is present, causes the rope to deteriorate rapidly. For a rope to conform to a change in the radius of curvature, every wire is required to bend and then to readjust itself. Thus, every section of a rope that passes over a sheave makes two complete flexures - once when it conforms to the circumference of the sheave and again when it straightens out. Experiments showed[8] that wire reached a fatigue limit of about 68,300 pounds per square inch under dry conditions with about 1,000,000 reversals but failed with the same number of reversals under a spray of tap water at about 47,600 pounds per square inch.

Microscopic examination of cross sections of corroded ropes has shown that the initial corrosion occurs chiefly on the inside surfaces of the outer wires when they make contact with the next layer, and as the corrosion proceeds it is found to be the most marked at the contact surfaces of strand with strand. Little corrosion has been found next to the fiber core. Water, which causes the principal damage, penetrates but a short distance into the rope; hence, it appears that the prime function of an internal lubricant is to seal the rope against entry of water. Once corrosion starts and the smooth contours of the wires are destroyed by etching and corrosion products, the relative motion of the wires speeds their destruction on account of the friction.

Constant effort should be made to prevent corrosion from starting and to detect it when it has started. The only practical method of controlling corrosion is to lubricate correctly and frequently, and this may not be effective under all conditions; however, a rusty rope is a liability.

SHAFT GUIDES

Shaft guides seldom receive the attention they merit, and the reports of falling-cage accidents usually tell of guides being torn loose from their fastenings, or broken, when the safety catches function; hence, the guides do not perform one of their main functions or requirements.

Many shaft guides are made of wood and attached to the shaft timbers with bolted angle irons or with lag screws. Standards have not been establis regulating the dimensions of shaft guides or their methods of attachment, but they should be large enough and tough enough to withstand the gripping power of the safety catches, and they should be firmly and positively attached to the shaft timbers. The use of lag screws to attach the guides to the shaft timbers is common practice, but some authorities do not consider this method to be satisfactory, as the lag screws may corrode and loosen, thus weakening the fastening, or they may pull out and catch between the guide and the cage shoe.

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[8] Dixon, S. M., Hogan, M. A., and Robertson, S. L., Deterioration of Collier Winding Ropes: Safety in Mines Research Board Paper No. 94, 1936.

Long-leaf yellow pine is regarded in the United States as the best wood for shaft guides because of the straight grain, hardness, and strength. Oregon pine is also good for this purpose, but oak is not recommended, as it may splinter, warp, and twist out of line in seasoning. Red or Norway pine is thought to be the best of the soft woods. In Canada, tests have shown that British Columbia fir is the most satisfactory timber for shaft guides, and most of the mines in Ontario use this wood; spruce is regarded as less satisfactory than fir.

The dimensions of the guides depend on the weight of the cage and speed of hoisting and to some extent the type of safety catches used. In practice, the size ranges from 4 by 4 inches for small cages and slow speed to 6 by 8 inches for heavy duty.

The timbers used for guides should be long enough so that the splices come at the shaft timbers, though some authorities claim this is not important if the splices are long and the shaft timbers are placed not more than 4 feet apart.

The clearance between guides and cage shoes is generally 1/4 to 1/2 inch; in heavy ground, where it is difficult to maintain the correct gage, the greater clearance is preferred.

Wooden shaft guides should be inspected thoroughly at weekly intervals by a competent person; inspection should include the physical condition of the guides and the lag screws or other fastenings, fit of the cage shoes, checking for tight joints, and alinement of guides. Plug or other suitable tests to determine the extent of the decay should be made at intervals of not more than 6 months.

Steel guides are used instead of wood in some mine shafts, particularly in concrete-lined shafts where heavy cages and high hoisting speeds are used. Some of the advantages of steel guides are that they are noncombustible, keep their alinement, and wear better than wooden guides; moreover, the steel does not change dimension when wet, and therefore a smaller clearance can be maintained between the guide and cage shoe. Some authorities condemn steel guides, stating that the coefficient of friction between the steel surfaces varies with the condition of the guides, which are sometimes dry and sometimes slimy, so that the braking effect would be alternately too fast or too slow.

The standard T-rail is the most common rolled section used for guides. The weight of the rail commonly used ranges from 60 to 100 pounds per linear yard. The rails are bolted to buntons and connected by standard splice bars.

In the United States, the almost universal practice is to place guides, either wood or steel, on opposite sides of the hoisting compartment. In some European mines the guides are placed on one side of the compartment, and the cage or skip is suspended in such a manner that it is pulled against the guides. Safety catches are not used in such mines.

Rope guides are used in many British coal mines.[9] Four steel guide ropes, generally of the locked-coil type, are suspended in the shaft compartment, one at each corner of the cage, and kept taut with weights. The weights used vary according to the depth of the shaft, but roughly 1 ton of weight is provided for each 300 feet of depth. The guide ropes in the same shaft are not weighted equally; by varying the loading, the periodicity of the vibration of the ropes is altered. Sometimes springs are employed to keep the ropes taut. The guide ropes pass through rings placed below the cage floor; and to prevent the cages from colliding at a passing point, two rubbing ropes are placed between the sides of the cages and kept taut. The advantages claimed for wire rope guides are that they require little repairing and there is not much jar in hoisting and little interference with the ventilating air current. The disadvantage is that efficient safety catches cannot be employed and therefore are not used; hence, reliance for safety is upon careful inspection of all ropes; wire rope guides seldom are used in the mines of Continental Europe, chiefly for this reason.

EFFECT OF TRAILING ROPES

Trailing rope in a falling-cage accident is the term applied to the portion of the broken hoisting rope that is attached to the falling shaft conveyance.

Trailing ropes exert a decidedly harmful influence upon the performance of safety catches in case a hoisting rope breaks. This is particularly so when the trailing rope is relatively long, as the drag developed tends to prevent the safety dogs from setting and also to release them after they have already engaged.

The weight of a long trailing rope and the impact with which it strikes a cage that has been stopped by the safety catches has been known to tear the teeth of the safety dog out of the wooden guides or to shear the guides and thereby cause the cage to resume its fall. The design of safety catches that will be effective in all cases of hoisting-rope failure must include provision for taking care of the trailing-rope effect; otherwise the safety catche probably will be unsuccessful in emergencies owing to rope breakage.

The Ontario statistics recording the performance of safety catches in arresting the fall of mine cages due to accidents arising from rope breakage, failure of hoisting machinery, or fouling include 33 instances, 5 of which were uncertain or where the safety catches did not have an opportunity to function. In 18 instances the safety devices stopped the cage, and in 10 instances they did not; therefore, the safety catches were effective in stopping the cage in only 64 percent of the Ontario accidents that are fully recorded. In several of the accidents the cage was stopped within a very short distance, and so far as is known no serious injuries were sustained by the occupants of cages.

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[9] Rice, George S., and Hartmann, Irving, Coal Mining in Europe: Bureau of Mines Bull. 414, 1939, 369 pp.

Table 4 lists the accidents in which the safety catches failed to hold the cage, and it is significant to note that in 10 instances of safety-catch failure, 8 involved trailing ropes 200 to 4,000 feet in length.

TABLE 4. - Falling-cage accidents where the safety catches did not stop the falling cage

Cause of accident	Weight of empty conveyance, pounds	Probable cause of failure of safety catches to act satisfactorily	Length of trailing rope, feet	Remarks
Faulty braking; dogging on descent.	5,000	Clogged from initial dogging	30	
Rope failure........	?	Unknown	500.	Unsuitable rope.
Brake failed to hold..............	10,820	Trailing rope	4,000	Brake-clutch interlock was imperfect.
Frozen sheave.......	5,950	Clogging, and trailing rope	1,500	Rope broke.
Faulty braking (?), kinking (?)........	6,000	Prior clogging	200	Dogging, slack rope probable.
Cage froze to guides	3,250	Dogs probably frozen	0	Slack rope let out; cage fell; rope broke.
Clutch failed.......	?	Probably trailing rope	cage to drum	Brake failed to hold.
Sheave axle failed..	4,200	Bite too small	350	Rope broke.
Rope corrosion......	4,205	Bite too small, trailing rope	1,130	
Clutch slipped......	2,200	Trailing rope	2,600	

CAGE SAFETY DEVICES

The widely varying situations under which safety catches may be required to function are seldom realized. A device that will function satisfactorily when the cage is ascending may be useless if the cage is descending at a rapid rate; or a device that will function effectively with an empty cage may be inadequate to stop a loaded cage from falling; or a safety catch might stop a rapidly descending cage so quickly that the occupants would be injured or killed.

The current methods of operating a mine hoist cause the tension on the hoisting rope to fluctuate considerably while the cage or skip is being raised or lowered; the hoisting rope is likely to vibrate or oscillate longitudinally when the cage movement is retarded or accelerated. Retarding a descending cage by the hoist brakes increases the rope tension, as the momentum of the cage or skip must be arrested; applying the hoist brakes when the cage is ascending diminishes the rope tension; and vibrations or longitudinal oscillations of the hoist rope occur in either case. Mathematical calculations show that if the deceleration exceeds about one-half the acceleration of gravity, the tension of the rope may fall to zero during the longitudinal oscillations; and then the cage, falling back on the slack rope, produces a dangerously increased tension. Also, particularly large tensions may arise from "grabby" brakes, and important vibrating or oscillatory effects may be produced by starting a hoist with a slack rope. Safety catches must be designed so as to function only in an emergency rather than in case of rope-tension changes such as those just mentioned.

DESIRABLE CHARACTERISTICS OF CAGE SAFETY DEVICES

The committee investigating the falling-cage accident at the Paymaster Consolidated Mines, Inc., prepared a comprehensive list of the desirable characteristics of cage safety devices as a suggested guide in the future design of this type of equipment. This list follows:

1. The device must be simple, rugged, and reliable, should permit ready inspection, cleaning, or repair, and should require a minimum amount of attention and skill in maintenance.

2. It must be immediate and automatic in action.

3. If applied to the guides, it must act on both sides at once, so that the forces are balanced and the guides will not buckle excessively.

4. It should be self-adjusting to make allowance for guide wear.

5. It must be strong enough to stop a fully loaded cage at the prevailing speed of operation and hold it until the occupants are released.

6. It should preferably be of such form that it can be applied to existing cages, skips or hoisting machinery, without excessive cost.

7. It must stop the cage within a reasonable distance but not so suddenly as to subject the occupants to possible serious injury or death.

8. It must not release itself if the tension is again applied to a broken rope. In some of the designs now used, the dogs may begin to grip the guides and then, if the tension is again applied to the trailing cable, they will be automatically withdrawn from the guides and the cage will fall freely. Some of the dogs illustrated in this report are so designed that, once they have passed through a certain degree of rotation, a re-application of the rope tension will increase their grip on the guides, giving an added degree of security. This feature should be incorporated in the safety device wherever possible.

9. It must not be applied accidentally when the cage is bouncing.

10. It must be comparatively easy to disengage after testing.

11. Its operation should preferably be independent of variations in the coefficient of friction between the braking surface and the guides.

12. It must work satisfactorily under bad operating conditions, such as those produced by water, dirt, or ice.

13. If fluid pressures are employed, it must not be put out of action by leakage of water, oil, or air at the joints.

14. If it is mechanical in form, it must not be liable to stick from want of a reasonable amount of lubrication or bad adjustment.

15. It must not become useless in an emergency by being clogged with shavings or other foreign matter.

16. It must be actuated by a spring or other positive device. Mechanisms operated solely by a weight mounted in or on the cage are useless.

17. It must be suitable for deep mines and heavy cables.

18. If possible, it should be put into operation whenever speeds become excessive and be actuated by these excesses rather than by a reduction or loss of tension on the hoisting rope.

19. It must be dependable despite the effects of a trailing rope.

20. It must operate effectively if the hoisting machinery should get out of control through clutch or brake failure..

21. It must be brought into operation immediately after the cage starts to fall and before a high velocity has been built up, as would happen if sole reliance were placed on a cushioning chamber at the bottom of the shaft.

RESULTS OF TESTING CAGE SAFETY DEVICES

A large number of tests of existing and experimental safety devices were made in Ontario by the various mining companies with the cooperation of the Department of Mines and the Committee investigating the Paymaster Consolidated Inc., falling-cage accident. Cut of 116 tests reported, the safety dogs failed to act satisfactorily 14 times, or 12.1 percent. The number of failure of the safety dogs to function satisfactorily does not represent actual mine practice, as they included tests to determine possible limits of design or operation.

The apparent causes of the unsatisfactory performance are listed below:

Safety dogs turned over....................	5
Clogging of the teeth of the safety dogs...	3
Shaft guides buckled.......................	2
Faulty guides or joints....................	2
Trailing rope effect.......................	1
Safety dog teeth too short.................	1
	14

The tests showed that in 13 failure cases where the dogs did not stop the cage, the velocities at the instant of the first engagement of dogs ranged from 900 to 1,630 feet per minute, with 8 of them below 1,200 feet per minute. Faulty performance cannot therefore be attributed to difficulty in dealing with high velocities. In many instances successful performance of safety mechanisms was achieved with velocities ranging from 1,200 to over 2,000 feet per minute. Apart from trailing-rope complications, therefore, safety installations have been made to act about equally satisfactorily for high and low velocities.

Table 5 is a list of typical examples of the conditions under which the tests were conducted. It should be noted that the tests were made with loaded cages after a free fall of several feet.

TABLE 5. - Typical results of falling-cage tests made at Ontario mines

Total free fall, feet	Stopping distance, feet	Velocity at engagement of dogs ft. per. min.	Weight of conveyance, pounds	Weight of loaded conveyance, pounds	Safety dog width, inches	Initial spring force, pounds
8.92	16.67	1435	12,000	19,200	?	7500
8.10	5.37	1370	10,000	16,300	3	6000
7.37	10.12	1310	5,393	9,793	3	2800
8.17	6.00	1375	4,800	6,600	3	1660
6.96	8.25	1270	5,800	10,660	?	3500
7.00	7.50	1270	8,800	13,800	?	2500
7.08	1.92	1280	4,380	7,380	3	2800
7.75	1.42	1340	4,380	7,380	3	2000
6.25	6.33	1200	12,290	16,200	4½	2174
10.33	3.33	1540	7,600	17,600	2½	5311
10.25	7.63	1540	7,600	17,600	1½	5311
6.25	1.92	1200	4,700	6,700	3¼	2500
15.08	20.08	1870	10,160	12,160	3-3/4	4000
7.67	5.00	1335	2,300	3,500	3/4	750
5.92	0.50	1165	2,900	4,900	2½	1000
6.38	1.33	1210	4,680	6,680	2	4400

DESIGN OF SAFETY DOGS

Safety dogs of many designs are in use in the mines of the United States and Canada, and so far as is known no attempt has been made to standardize the design of this equipment. The number and shape of the dog teeth, whether the teeth are self-cleaning or likely to clog, and the width of the teeth are important factors of design.

Number of Teeth in Safety Dogs

In the tests made in Ontario, the design of the safety dogs is available in 13 out of 14 instances where the safety dogs did not stop the falling cage. One type had 3 teeth, five had 4 teeth, two had 5 teeth, three had 6 teeth, one had 8 peg teeth, and one had 2 offset wedge type.

The safety dogs with small teeth clogged frequently with wood shavings and splinters, and as a result there is a definite tendency to use dogs with fewer and longer teeth and with design features that provide means of clearing away the shavings.

Width of Safety-Dog Face

Examination of the instances of test failure in Ontario fails to disclose a clear relationship between the width of the face of the dog and the final result. The effect of width is influenced greatly by the clear distance between guides and whether the full face of the dog makes contact with the guide. Obviously, if part of the width of the dog does not come in contact with the guide, it cannot be effective.

Deceleration Ratio

The deceleration ratio is defined as the ratio of the deceleration of the falling cage to the acceleration due to gravity. This is of importance in the design of safety catches, as if the cage is descending rapidly when the safety catches function, too abrupt a stop may kill or injure all of the occupants of the cage.

Definite standards for the deceleration ratio for mine cages have not been established; the Ontario Committee investigating the falling-cage accident at Paymaster Consolidated Mines, Inc., recommended that a deceleration ratio of 3.0 be established in future designs of cage safety catches. This is in excess of the standard of 2.5 established by the Canadian Standards Association for Passenger and Freight Elevators.

An example of the importance of this ratio in the design of safety catches is an accident that occurred at the Hallnor mine in Ontario on September 18, 1945. The safety catches on a descending cage functioned owing to a displaced wear plate; the deceleration ratio was estimated to be approximately 4.0. Minor injuries were suffered by four of the nine occupants of the cage.

Value of Stops in Limiting Rotation of Safety Dogs

Safety dogs are prevented from rotating too far, after engaging the guide, by stops that are integral with the safety dog or by linkage limitation. In the Ontario tests, of the 13 cases where the cage was not stopped by the safety catches, one occurred with dogs having cage stops, four with guide stops, four with linkage limitations only; one with cage stops and guide stops, and three with guide stops and shaft stops. The tests did not reveal any clear superiority of one type of stop over another.

Excessive rotation of the safety dogs may not be prevented by guide stops; i.e., where the tail piece of the dog bears against the guide. The stops serve to compensate for guide wear, but many cut into the guide so deeply as to permit the dog to turn over unless the tail piece was widened or equipped with a pad. This happened in three of the 13 cases reported in the Ontario tests.

Ratio of Spring Force to Conveyance Weight

The springs used to force the safety dogs into contact with the shaft guides must be strong enough to cause them to function quickly, and yet they must not function in the normal bounce or lashing or whip of the hoisting rope. The springs should be in compression rather than in tension, as if the spring breaks, the operating force is reduced only a small percentage; if the spring is in tension and breaks, the operating force is reduced 100 percent.

Recommended American practice[10] is to use springs whose supporting powe is from 0.33 of the weight of the cage for small cages to 0.10 the weight for larger ones.

Tests conducted in Ontario included 100 cases in which the spring ratio was known. The results of these tests are shown in table 6. The tests did not reveal any clear indication of the correct spring-force ratio to use in the design of safety catches.

TABLE 6. - Ratio of initial spring force to weight of conveyance in drop tests

Ratio of initial spring force to conveyance weight	Number of cases	
	Successful tests	Unsuccessful test
0 - 0.25	3	1
0.26 - 0.40	32	3
0.41 - 0.50	3	0
0.51 - 0.60	12	2
0.61 - 0.70	18	1
0.71 - 0.80	17	2
0.81 - 1.00	4	2

Note: Velocity of the falling cage at engagement of the safety dogs ranged from 825 to 2040 feet per minute.

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[10] Mining Engineers' Handbook, 3d ed., Robert Peele, Editor, 1941.

It is obvious that factors other than the initial spring force affect the successful operation of safety catches on mine cages.

TESTING MINE CAGE SAFETY CATCHES

It is of utmost importance that safety catches on mine cages be kept in condition to operate positively and efficiently in the event the hoisting rope breaks. The safety catches should be inspected daily, and the necessary maintenance work should be performed as soon as anything is discovered to be out of order. Tests should be made at regular intervals, preferably at least once each month.

Methods of testing safety catches on mine cages vary widely, and the conditions under which the tests are made are far from standardized. At some mines, the empty stationary cage is dropped and a record is made of the distance it falls after the safety dogs bite into the wooden guide; at other mines the cage is loaded before it is allowed to fall. In other cases the mine cage is allowed a free fall of a few feet before the test device is permitted to function.

Some of the methods of testing safety catches on mine cages have been described in earlier publications[11]/[12]/ of the Bureau of Mines, some of which are no longer available for distribution. Much of the information contained in these publications as relating to individual mines is reproduced below.

Devices that free the cage from the hoisting rope in order to simulate a falling cage are generally made in local mine shops; several of these designs are shown in the accompanying illustrations and may serve as a guide to mining officials who may wish to install similar devices.

Eastern Bituminous Mines[11]/

Methods of Testing

Three general methods are followed in testing the effectiveness of the safety-catch action:

1. The rope is disconnected from the cage by inserting a "knock-off" device between the rope connection and the main drawbar of the cage. This method simulates the failure of a hoisting rope and subsequent release of the cage.

2. The rope is not disconnected from the cage for the test. The compression, or tension, as the condition may be, of the actuating spring is transferred to some other medium, such as a releasing pin, which is part of a release mechanism. In other instances, the spring pressure is transferred

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[11]/ Sloman, H. J., Testing Safety Catches on Mine Cages at Some Eastern Bituminous Coal Mines: Bureau of Mines Inf. Circ. 7290, 1944, 20 pp.

[12]/ Pearce, C. M., and Cash, F. E., Testing Safety Catches on Mine Cages, Lake Superior District: Bureau of Mines Inf. Circ. 7325, 1945, 12 pp.

to a lifting jack, which may be jerked away during a downward movement of the cage and thus permit the safety catches to function.

3. A test less severe than that explained in statement 2 is one in which the spring's kingpin is disconnected from its normal connection, allowing the safety catches to turn in position to grip the guides. Subsequent lowering of the cage permits the safety catches to tighten and grip the guides and suspend the cage in the hoisting shaft.

The methods of testing described in statements 2 and 3 have the advantage of obviating the necessity of blocking the shaft as a precaution against failure of the test, because the main rope and bridle-chain connections are not disturbed.

The tests are conducted at the top of the shaft in some instances and at the bottom in others.

Details of Safety-Catch Testing Methods

Mine A. - Figure 1 illustrates the method of testing safety catches on a cage equipped with cam-shaped safety catches, which, when actuated, grip the sides of the head of a 100-pound rail used as a cage guide. The rope is released from the cage in this test.

The hoisting rope is attached to the cage with an open-type rope socket, which is pin-connected to an eye in the main drawbar. The opposite end of the main drawbar serves as a kingpin for the spring, which is in compression during normal hoisting operations with tension in the hoisting rope. The two jack shafts are rotated a fraction of a revolution during normal hoisting, so that the safety catches are out of contact with the cage guides.

An empty cage is raised above the surface landing of the shaft, and two 10- by 10-inch timbers are placed across the shaft. The hoisting engineer is signaled to lower the cage until it rests upon the timbers.

Two workmen wearing safety belts mount the cage bonnet, and a signal is given the hoisting engineer to slack the rope. The rope-socket and bridle-chain connections are removed by the workmen. A link and a hinged knock-off hook are inserted, the link being connected to the rope socket by a pin, and the knock-off hook being attached to the eye of the main drawbar. A pivoted lever is attached to the knock-off hook; one end of the lever serves as a retaining bail, and the other end has a hemp rope attached to it for releasin the hook. After insertion of this attachment, the men leave the cage, and o of them stands on a horizontal member of the head frame. The hoisting engin is signaled to raise the cage to about 6 inches above the 10 by 10 timbers, s that tension is in the main drawbar. The workman on the head frame actuates the knock-off hook by a downward jerk on the hemp rope attached to the lever. The safety catches function and hold the cage. The workmen then remount the cage bonnet, and the hoisting rope is again slacked sufficiently to disconnec the knock-off hook and link. The rope socket is reconnected to the eye of th main drawbar, and the bridle chains are replaced in their proper position. The hoisting engineer is signaled to raise the cage; the actuating spring for

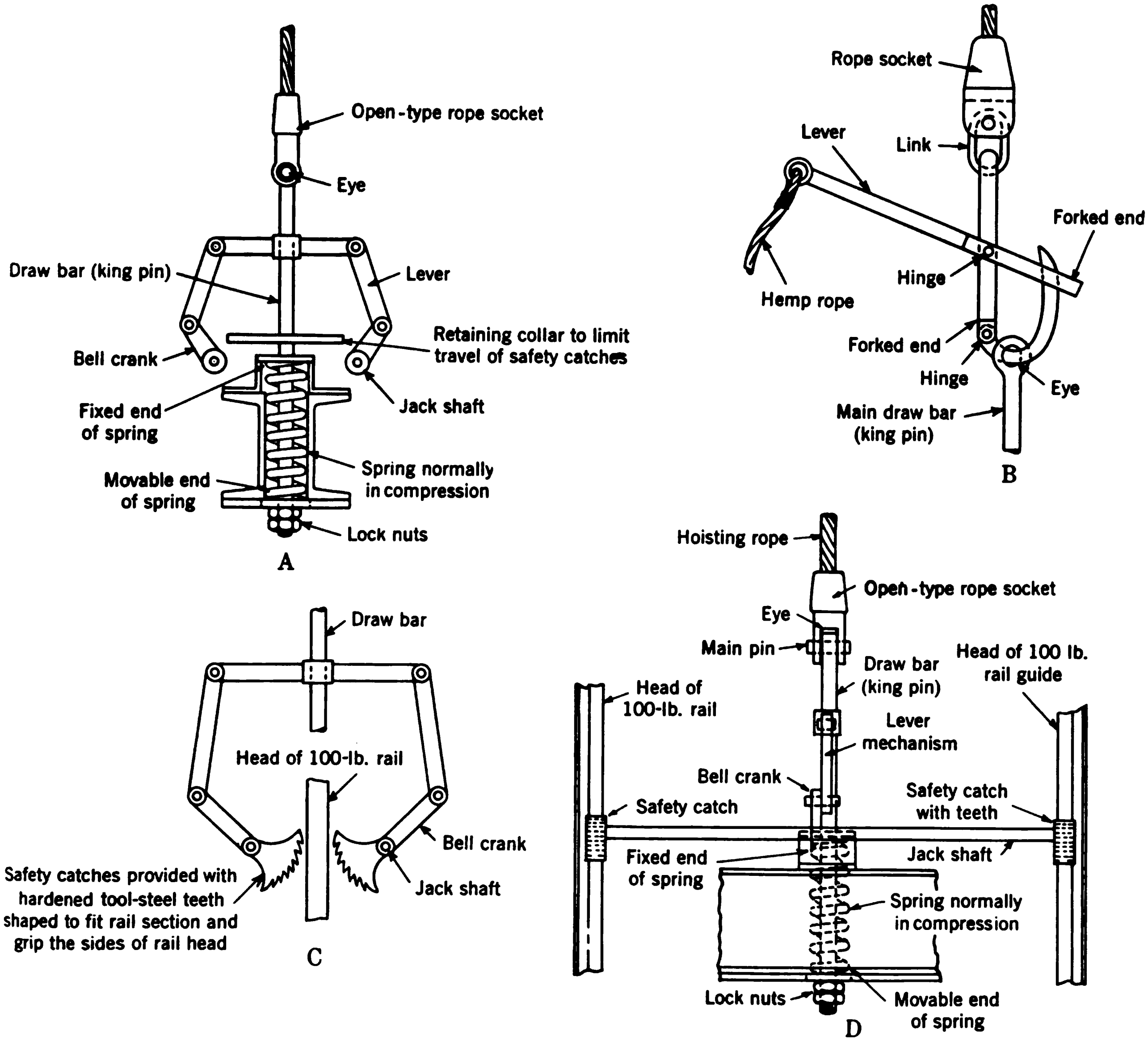

Figure 1. - A, Safety catch-actuating mechanism; B, Knock-off device; C, Safety catches in position to grip guide; D, Jack shaft with safety catches in position (near side) and actuating mechanism. Mine A.

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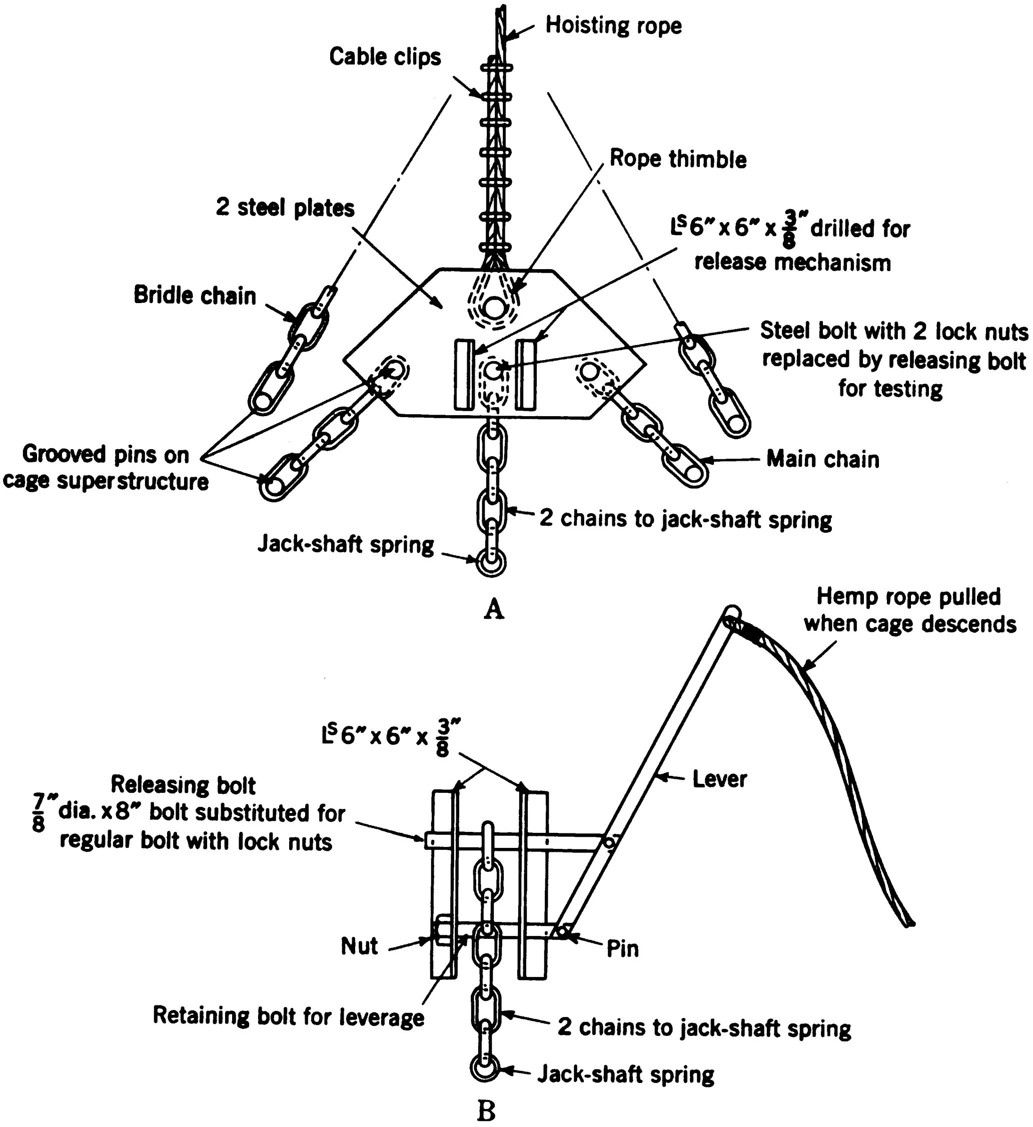
Hoisting rope
Cable clips
Rope thimble
2 steel plates
L^S 6" x 6" x $\frac{3}{8}$" drilled for release mechanism
Bridle chain
Steel bolt with 2 lock nuts replaced by releasing bolt for testing
Grooved pins on cage superstructure
Main chain
2 chains to jack-shaft spring
Jack-shaft spring
A
Hemp rope pulled when cage descends
L^S 6" x 6" x $\frac{3}{8}$"
Releasing bolt
$\frac{7}{8}$" dia. x 8" bolt substituted for regular bolt with lock nuts
Lever
Nut
Pin
Retaining bolt for leverage
2 chains to jack-shaft spring
Jack-shaft spring
B

Figure 2. - A, Cage connections; B, Releasing mechanism for testing cage safety catches. Mine B.

the jack shafts is recompressed when tension is in the hoisting rope, and the safety catches are released. The timbers are removed from across the shaft, and normal hoisting is resumed.

One cage dropped 5 inches when the safety catches functioned and held it; the other cage was suspended after a $2\frac{1}{4}$-inch drop in successive tests.

Mine B. - Figure 2 illustrates the main drawbar attachments and the releasing mechanism for testing the safety catches on cages at mine B. The hoisting rope is attached to the cage by means of a thimble and seven cable clips. Wooden cage guides are installed. The cage is equipped with clam-shaped, toothed safety catches, which have fins cast on each to serve as counterweights, which assist the gripping action when the safety catches function and limit the extent of their movement. The jack-shaft actuating spring lies in a horizontal plane and is attached to the two jack shafts by means of right- and left-hand bell cranks. The spring is in compression when tension is in the hoisting rope, and for normal operation of the cage the safety catches are disengaged from the guides.

A safety catch-testing device is attached to the superstructure of an empty cage in a manner that permits the transfer of the jack-shaft spring compression to a releasing pin without disturbing either the main-rope thimble connection to the cage or the bridle-chain connections. The cage is lowered below the surface landing, so that two workmen can mount the bonnet and make the necessary attachments to the cage. Safety belts are worn by the workmen, and their safety ropes are attached to the head frame. At this point in the test, the workmen leave the cage and take positions on the surface adjacent to the shaft so as to actuate the release mechanism from a place of safety. The cage is then raised in the head frame until the platform is about 10 feet above the surface landing and is brought to rest. The hoisting engineer is signaled to lower the cage, and the pin-releasing mechanism is operated by one of the workmen pulling on a hemp rope attached to the releasing lever after the cage has descended 4 or 5 feet. When the pin is withdrawn, the spring is released, the jack shafts rotate toward each other a fraction of one revolution, and the safety catches turn toward the guides and grip them. This operation takes place almost instantaneously, because the cage does not descend more than $3\frac{1}{2}$ inches after the lever rope is pulled. The entire weight of the cage is borne by the safety catches, because slack in the hoisting rope was noted, indicating that the cage weight was not being supported by the rope after the safety catches functioned.

The hoisting shaft was not blocked to prevent descent of the cage if the safety catches had not functioned, because the main hoisting rope was not disconnected from the cage during the tests. The hoisting engineer could stop the cage, if the safety catches failed to grip the guides.

After the safety catches have functioned, the two workmen again go to the top of the cage, compress the spring to release the safety catches, and replace the releasing pin with the original pin, which keeps the jack shafts in position for normal hoisting. The entire releasing mechanism is removed from the top of the cage, the workmen descend, and normal hoisting operations are resumed.

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Mine C. - The cage connections for main chains, bridle chains, and jackshaft springs are shown in figure 3. The hoisting rope is attached to the cage by a spelter-filled socket, and the two jack shafts are actuated by two vertical springs, one for each jack shaft, which are in compression when tension is in the hoisting rope. Wooden cage guides are installed throughout the hoisting distance. Cam-shaped safety catches are at each extremity of the two jack shafts, and they grip the guides when the safety mechanism functions.

A releasing device similar to that in figure 4 is attached to the superstructure of the cage when safety catches are to be tested. This device permits transfers of the compression in the jack-shaft springs to a releasing pin without disturbing either the main rope-socket connection or the bridle-chain connections. The releasing device is installed by two workmen, who mount the top of the cage after the hoisting engineer has placed the cage in a convenient position near the surface landing. The workmen wear safety belts and attach their safety ropes to a substantial member of the steel head-frame structure. The workmen then leave the top of the cage and take positions on the surface adjacent to the shaft so as to actuate the release mechanism from a place of safety.

The hoisting engineer is signaled to lower the cage and, when the cage bonnet is about at the level of the surface landing, one of the workmen actuates the releasing mechanism by giving a quick, downward jerk on the hemp rope attached to the releasing lever. This action results in a quick withdrawal of the releasing pin; the jack-shaft springs expand; and the safety catches grip the guides. The operation takes place almost instantaneously, because the safety catches functioned after one cage had dropped $1\frac{1}{2}$ inches and the other had dropped 3 inches. In each test, slack was noted in the hoisting rope and bridge chains, indicating that the safety catches were bearing the weight of the cage after the release mechanism operated.

After the safety catches have functioned, the two workmen again go to the top of the cage, compress the springs with a steel pinch bar to release the safety catches from the guides, and replace the releasing pin with the original pin, which keeps the jack shafts and safety catches in proper position for normal hoisting. The entire releasing mechanism is removed from the top of the cage, the workmen descend, and normal hoisting operations can be resumed.

The hoisting shaft is not blocked, because the hoisting rope was not disconnected from the cage to make the test. If the safety catches should fail to function, the hoisting engineer could stop the cage, necessary adjustments or repairs could be made, and the test could be repeated.

Mine D. - Figure 5 illustrates the actuating mechanism for wedge-shaped safety catches, a detail of a wedge, and the "knock-off" device in use at this mine.

The hoisting rope is attached to the cage by means of a closed-type rope socket, pin-connected to two steel drawplates. Wedge-shaped safety catches,

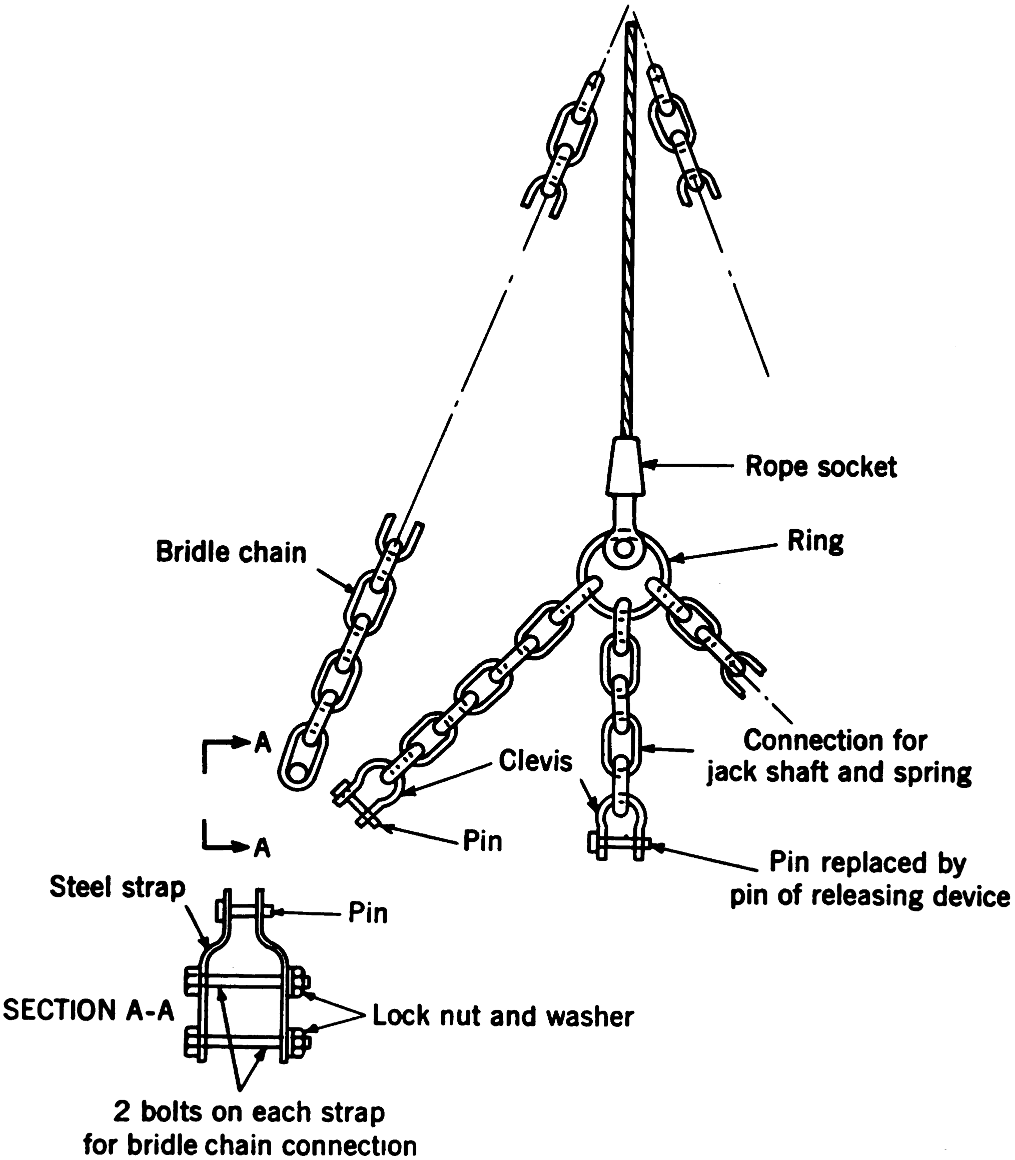
Rope socket
Ring
Bridle chain
A
A
Clevis
Connection for jack shaft and spring
Pin
Pin replaced by pin of releasing device
Steel strap
Pin
SECTION A-A
Lock nut and washer
2 bolts on each strap for bridle chain connection

Figure 3. - Safety-catch test. Mine C.

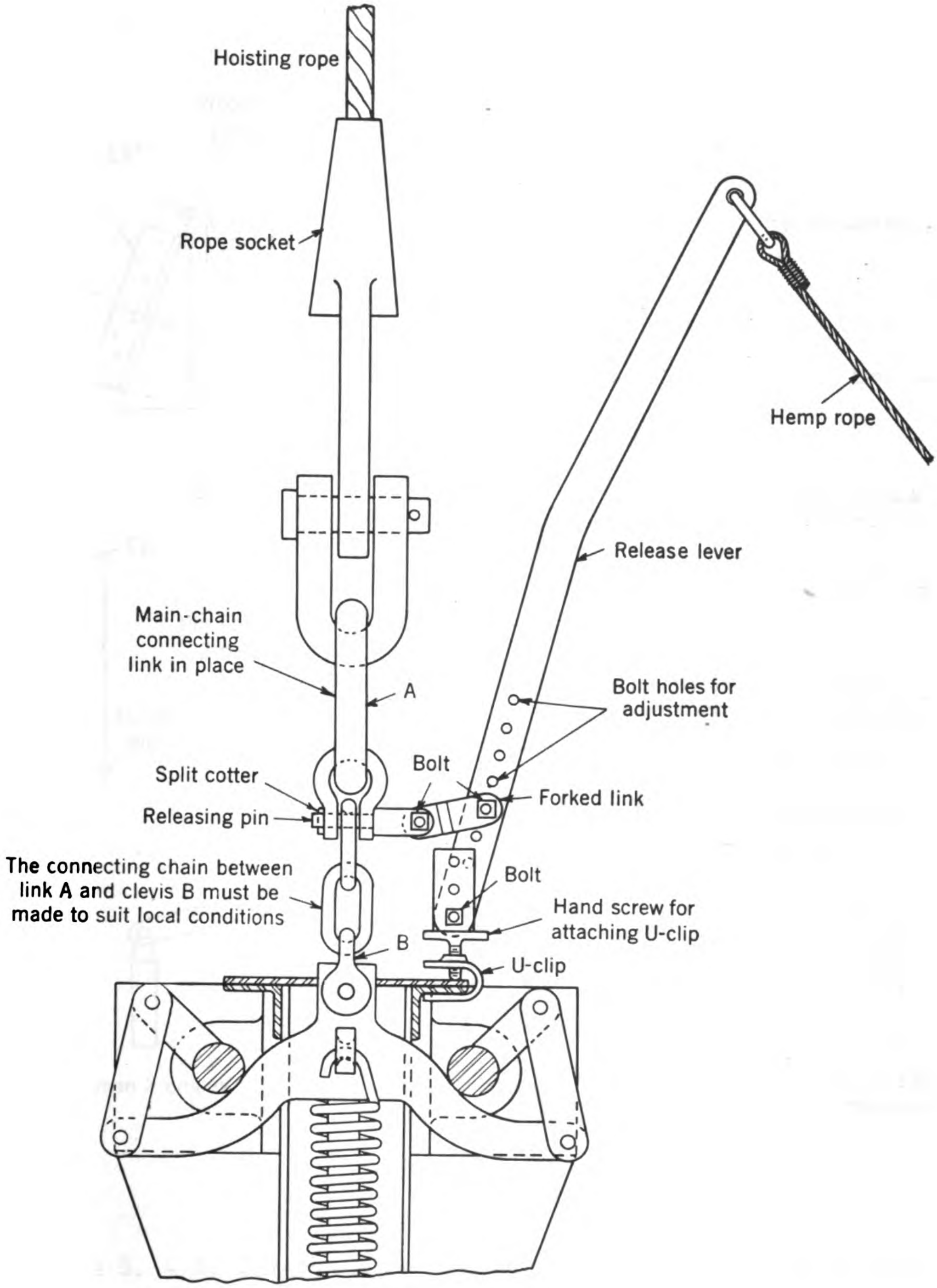
Hoisting rope
Rope socket
Hemp rope
Release lever
Main-chain connecting link in place
A
Bolt holes for adjustment
Split cotter
Bolt
Forked link
Releasing pin
The connecting chain between link A and clevis B must be made to suit local conditions
Bolt
Hand screw for attaching U-clip
B
U-clip

Figure 4. - Releasing device for testing safety catches on mine cage.

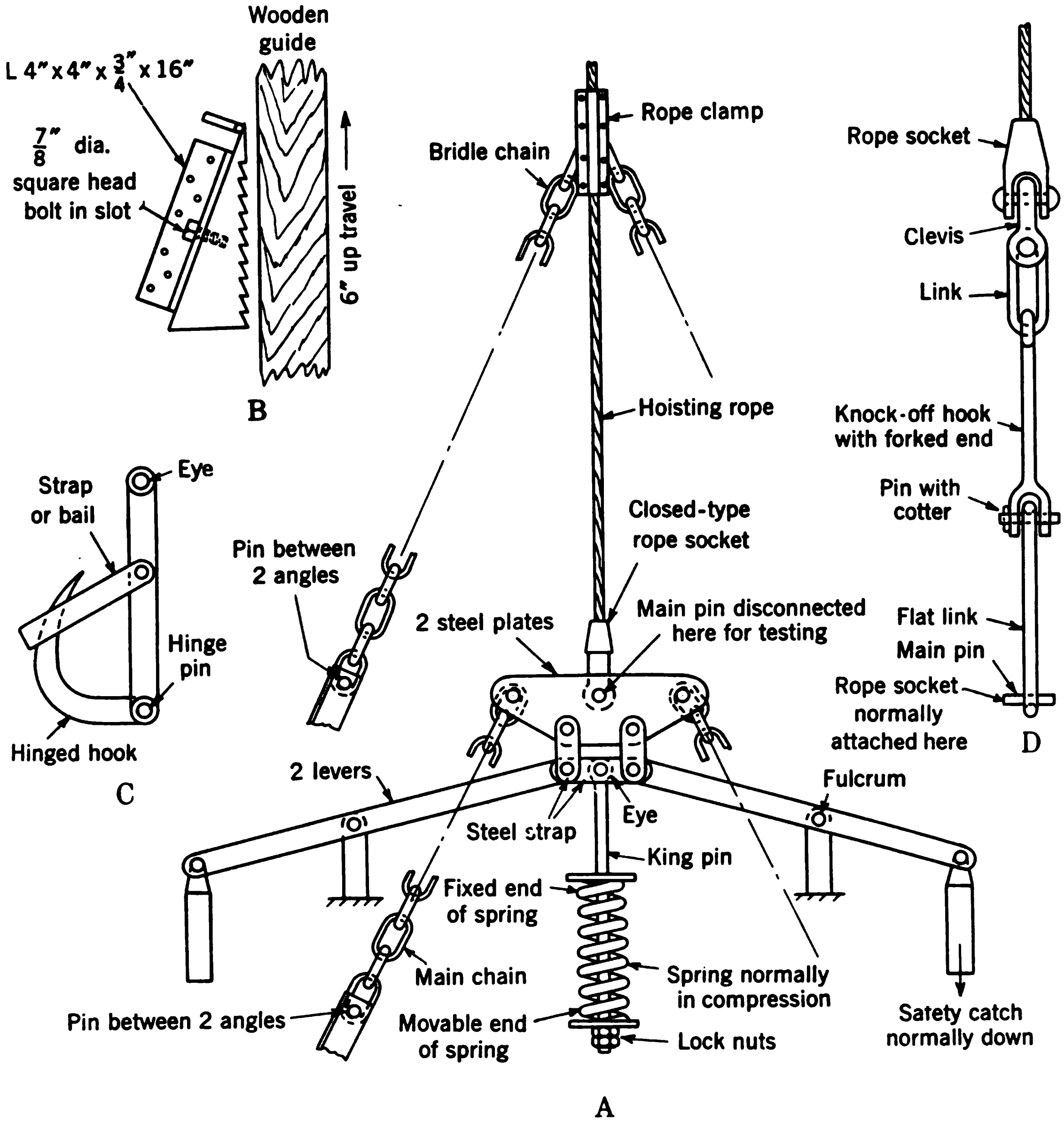

Figure 5. - A, Safety-catch mechanism; B, Safety-catch detail; C, Knock-off hook; D, Knock-off device. Mine D.

two for each guide, or four to a cage, are installed. Each wedge has a serrated face for contact with a wooden guide when the safety catches function. The catches are mounted on each cage in such a manner that when a pair is in the gripping position, their serrated faces would be only 2-3/4 inches apart if no guide intervened for them to apply the "bite" of the contact faces. In this instance, the wooden guides had cross-section dimensions of 5 by 8 inches and were installed so that the 5-inch thickness was between each pair of safety catches.

The safety catches are actuated by a system of levers and fulcrums. In normal hoisting operations, with tension in the hoisting rope, the catches are disengaged and held in a "down" postion. An actuating spring, which is connected by a kingpin to the main drawbar connection of the cage, is compressed between two steel plates when tension is in the main hoisting rope. Each safety catch is guided by a slotted shoe made of 4- by 4- by 3/4-inch angle iron about 16 inches long, with a 6-inch slot. A square-head bolt is attached to the safety catch, and the head of the bolt slides in the slot when the safety catch functions and controls the extent of its movement. The slotted shoes are mounted on the cage inclined at an angle with the vertical, so that when the safety catches function they are guided so as to permit a wedging action, and the 6-inch travel in the slot gives impetus to the action of the wedge-shaped safety catch, which moves "up" when functioning.

The test for effectiveness of the safety catch is conducted at the shaft bottom. The bridle chains are released at the surface before the test cage is lowered to the shaft bottom. A shallow sump is at the bottom of the shaft, and two bales of hay are placed in it; one bale is adjacent to each guide. The cage is lowered, upon signal to the hoisting engineer, until it rests upon the two bales of hay; this allows the cage deck to descend to 6 inches above the bottom landing and gives slack in the hoisting rope. A workman mounts the top of the cage and disconnects the rope socket from the main pin connection to the cage. A knock-off device is inserted between the rope socket and the cage. The knock-off device consists of a clevis (attached to rope socket), a 7/8-inch-diameter by 6-inch-long link, a hinged knock-off hook with a retaining strap, and a 16-inch flat link connected to the main pin on the cage.

The hoisting engineer is signaled to raise the cage a short distance, and the workman on the cage steps off onto a horizontal shaft timber. The workman then strikes the retaining strap with a short iron bar, releasing the knock-off hook and, in turn, the rope is released and the safety catches function.

Both cages were tested empty. One cage dropped 6 inches and the other dropped 9 inches in successive tests. All safety catches gripped the guides.

The workman remounted the cage, disconnected the knock-off attachment, reconnected the rope socket, and descended to the shaft bottom. The hoisting engineer was signaled to raise the cage, the safety catches were released when tension was applied to the hoisting rope, and normal hoisting could be resumed

Mine E. - The safety-catch mechanism on the man cages at this mine is illustrated in figure 6. The design of the levers and the method of suspension are unlike any of those described heretofore. The wedge-shaped safety catches function somewhat as described under mine D. One spring, in compression during normal hoisting, actuates all the safety catches through the kingpin connection shown in figure 6. The hoisting rope is equipped with an open rope socket, which is connected to the main drawplates through a solid link.

The safety catches are kept disengaged from the cage guides during normal hoisting by the tension in the hoisting rope. The kingpin is in tension when the cage is suspended on the hoisting rope, and it is connected at its top by an eye to the horizontal lever, which is one of a system that actuates the safety catches when the hoisting-rope tension is released. The bottom of the kingpin connects with the spring by means of a retaining washer and locknuts. Yellow-pine guides are installed throughout the hoisting distance.

Preliminary to the safety-catch test, a flatcar made from a mine-car truck is run onto the cage; the car supports two 12- by 16-inch timbers somewhat longer than the shaft dimension parallel to the long dimension of the cage. Each of these timbers is surmounted by an 8- by 9-inch timber of equal length, and these, in turn, support short lengths of 6- by 6-inch timbers that are in a position to encounter the cross beam of the cage after the cage is lowered.

The cage is lowered so that its deck with the flatcar is below the surface landing; the timbers span the shaft, and the cage with flatcar is lowered away from them. The cage is lowered until its cross beam rests upon the timbers, which then support the cage while the hoisting rope is slack. Two workmen mount the bonnet of the cage and disconnect the main pin and bridle-chain pins, releasing the hoisting rope and the bridle chains. A knock-off device is inserted between the solid link attached to the rope socket and the main pin, which is through two drawplates. This device consists, from top to bottom, of two clevises, a knock-off hook, and round-iron link. The top clevis is connected to the solid link on the rope socket, and the lower link is connected to the main pin through the draw plates. The hoisting engineer is signaled to raise the cage from the supporting timbers until it is suspended on the hoisting rope about $2\frac{1}{2}$ feet above the timbers. One of the workmen has stationed himself on one of the cross members of the steel head frame and, by striking the retaining bail of the knock-off hook with a sledge hammer releases the cage from the hoisting rope. When tension is released from the hoisting rope, the compressed spring expands, the safety-catch levers turn about their fulcrums, and the safety catches rise in their retaining shoes and wedge themselves into the guides. Thus, after the No. 1 cage fell $5\frac{1}{2}$ inches, it was suspended on the cage guides. When the operation was repeated for No. 2 cage, it fell $7\frac{1}{2}$ inches before the safety catches gripped the guide and suspended the cage. The travel of the safety catches in their retaining shoes is controlled by a square-head bolt on the wedge sliding in a slot in the retaining shoe; a small recessed wearing plate is attached to the retaining shoe, so that the square-head bolt cannot turn, and the safety catch can move only in a predetermined direction.

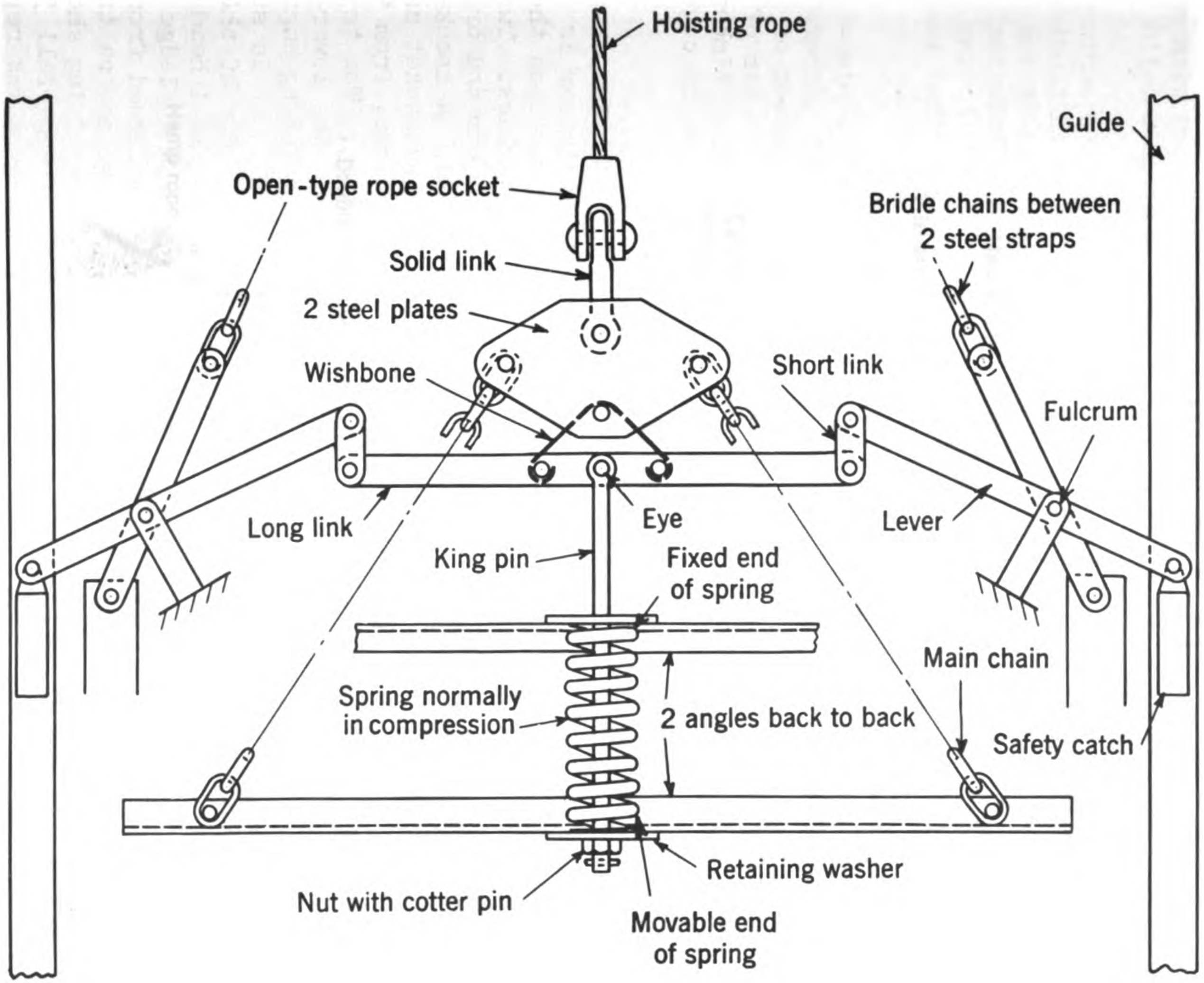

Figure 6. - Safety-catch mechanism. Mine E.

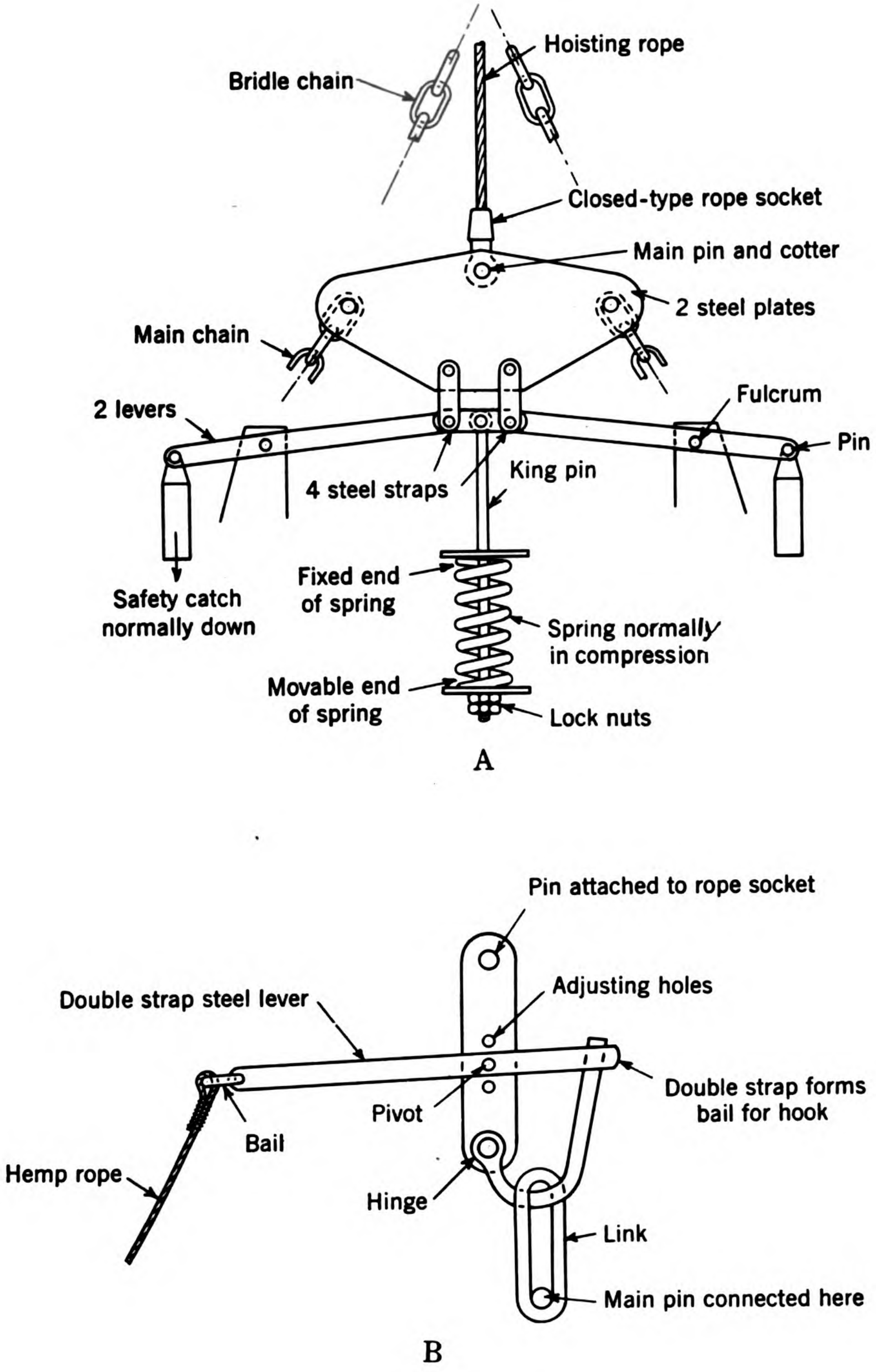

Figure 7. - A, Safety catch control mechanism;
B, Knock-off device. Mine F.

The knock-off hook is detached, and the rope socket is reconnected. Some tension is applied to the hoisting rope without disengaging the safety catches, and the fulcrum pins are removed. The cage is then lowered until its cross beam rests upon the timbers across the shaft. This procedure releases the safety catches, and they drop into the disengaged position in their retaining shoes without shock to the hoisting rope. The rope is slacked enough by the hoisting engineer to permit reinsertion of the fulcrum pins, and the bridle chains are reconnected.

The cage is raised by the hoisting engineer until the flatcar, which has remained on the cage during the test, engages and lifts the timbers from the surface shaft landing. The flatcar and timbers are pushed from cage No. 1, and cage No. 2 is brought to the surface landing. The car with timbers is run onto cage No. 2; the cage is lowered until the timbers engage and rest upon the shaft landing, whereupon the safety-catch test is repeated for cage 2.

Mine F. - The man cage at this mine differs from those usually found at coal mines. It is a single, counterweighted, totally enclosed, double-deck, rigid platform cage, which is used exclusively for hoisting men. Two ramps are constructed at the bottom and two at the top of the shaft, so that both decks can be loaded or unloaded simultaneously. Ten men are permitted on each deck, or a maximum of 20 men exclusive of the operator, who rides with the cage and controls its movement from the upper deck. The hoist that operates the man cage is in the main hoist house, which also contains the hoisting engine for the skip (production) shaft. The man-cage hoist can be operated from either the hoist house or the cage; the change-over from one position of operation to the other takes about 5 minutes. A lock-out device is provided, which is a safety feature that prevents operation of the man cage simultaneously from both positions. The cage movement was controlled from the hoist house during the safety-catch test.

The hoisting rope is connected to the cage by a closed rope socket. Bridle chains are connected to the hoisting rope above the rope socket by means of a rope clamp with ears, and the bridle-chain connections to the cage are independent of the main connections.

Wedge-shaped safety catches with serrated (toothed) surfaces are installed; the direction of travel of the safety catches is controlled by retaining shoes inclined with the vertical. Seventy-pound rails with their heads toward the center of the man shaft are installed as cage guides throughout the hoisting distance. The man cage is equipped with four safety catches, two for each rail guide. When the safety catches function, they grip the sides of the rail head.

Each safety catch is actuated by a lever that has a fulcrum near the center of the lever. The four levers are connected in such a manner that all are actuated, when tension is released from the hoisting rope, by a single coil spring, which is kept in compression during normal hoisting operations by its kingpin. The kingpin is in tension when tension is in the hoisting rope. The control mechanism is shown in figure 7.

The hoisting engineer is notified of the intent to test the man cage and, with the assistance of one man, changes the position of operation to the platform in the hoist house instead of the upper-cage deck. The engineer then takes his position on the operating platform in the hoist house. Upon receipt of the proper signal, the empty man cage is lowered until it rests upon wooden blocks at the bottom of the man shaft and the hoisting rope is slack. This places the top deck of the cage about 3 feet below its normal bottom landing. Two workmen proceed to the top of the cage from the upper deck through a trapdoor in the cage bonnet. The bridle chains are disconnected from the cage, and the rope socket is released from between the two main drawplates by removing the main pin connection. A knock-off hook and a link are inserted so that the rope socket is connected to the top of th knock-off hook. The top of the link is in the hook, and the bottom of the link is connected to the main pin. The hoisting engineer is notified throu the telephone on the man cage that this step has been completed. The proper signal is given to the engineer, and he operates the hoist so that the cage is lifted from its support until the top-deck platform is $3\frac{1}{2}$ inches from its normal bottom landing. The knock-off hook is equipped with a pivoted releasing lever shaped to form a bail around the hook at one end, whereas a hemp rope is attached to the other end of the lever. The workmen leave the top o the cage and proceed to a place of safety on the bottom landing. One of the workmen then releases the knock-off hook by a quick jerk on the hemp rope; this action releases the hoisting rope. The actuating spring expands, and the safety catches function by gripping the rail heads (guides) and suspend the cage in the shaft after a 6-inch drop. The two workmen again proceed t the top of the cage, and the engineer is signaled to lower the detached hoisting rope and knock-off hook. The knock-off hook is removed from the rope socket, and link is removed from the draw plates, and the rope socket and the bridle chains are reattached to the cage with their normal connectio The men dismount from the cage, and the hoisting engineer is signaled to ho the cage, whereupon, after tension is in the rope, the actuating spring is recompressed and the safety catches are disengaged. The engineer is signale to stop the cage and then to return it to the bottom landing. The cage telephone is utilized to notify the hoisting engineer that the safety-catch test has been completed, and he is instructed to make the change-over, so that th hoist can be operated from the upper-cage deck. After the change-over, the cage is taken to the surface landing, and the safety catches are examined t determine whether they have been damaged as a result of the test.

The company that operates this mine has introduced a special hoisting signal code when safety catches are tested, when repairs are made to the cag and its appurtenances, when any repairs are made in the shaft, or when repai and adjustments are made to the appliances on the head frame or top works. The signal system adopted utilizes loud gongs in the hoist house and at the cage landings and a gong on the man cage, all interconnected, so that when one is operated the sound is heard at each place on the signal system.

When the safety catches are tested, or when work is done on the shaft o head-frame equipment, each signal is preceded by five bells, and the enginee answers with five bells before the proper raise or lower signal is given. The five-bell signal does not precede the "stop" signal; just one bell is

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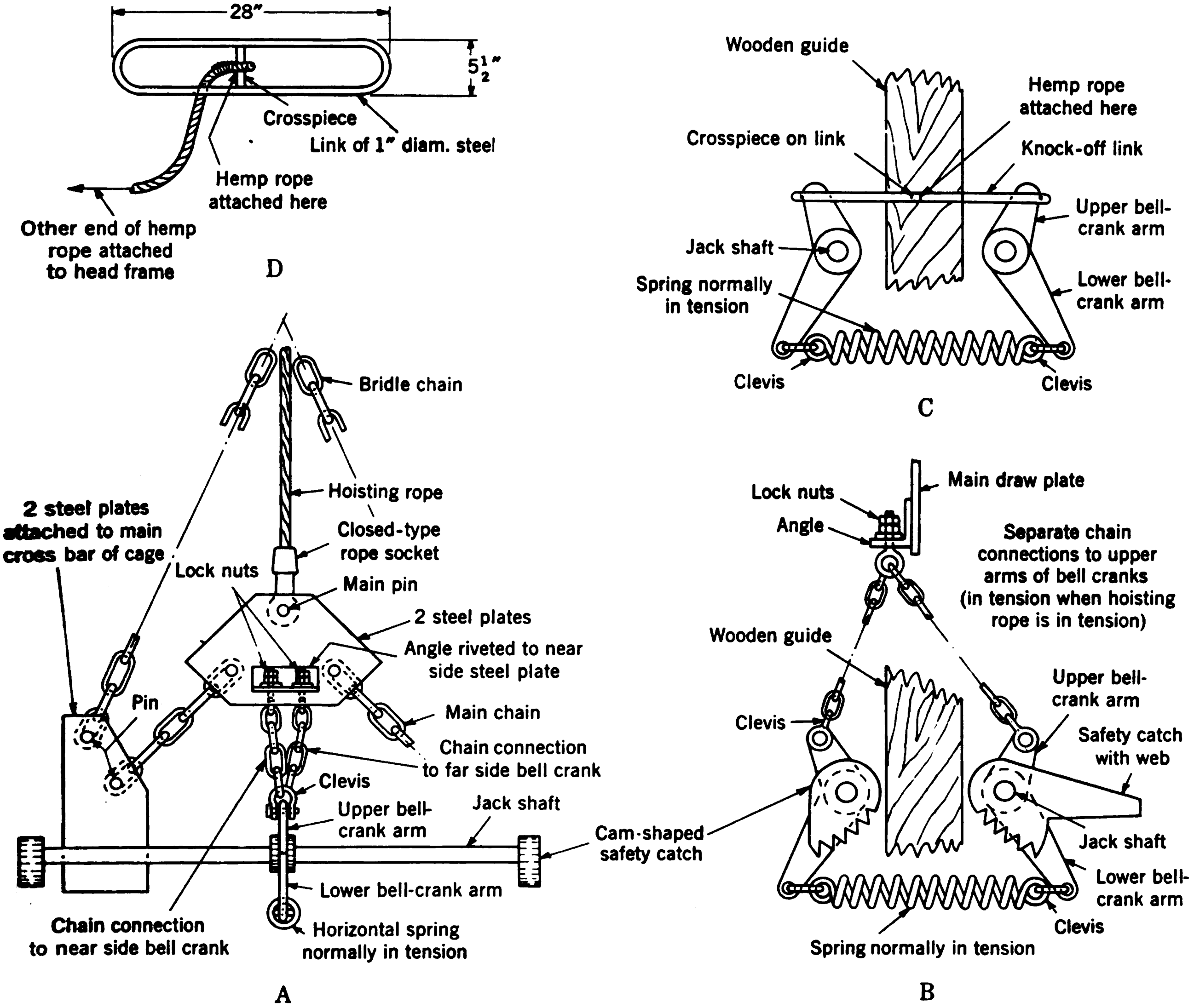

Figure 8. - A, Safety-catch mechanism showing near-side Jack shaft with safety catches and bell crank; B, Shows bell cranks and safety catches in disengaged position when cage is suspended on hoisting rope, C, Knock-off link in position for making safety-catch test; D, Knock-off link. Mine G.

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given to stop when the cage is in motion. Under no circumstances will the hoisting engineer move the man cage upon telephone signal only. Some conversation is carried on during the safety-catch test, but only preliminary signals are given by telephone. The shaft signal system must be operated with the correct signals before the engineer will move the cage.

Mine G. - Figure 8 illustrates the safety-catch mechanism together with the hoisting rope, main-chain, and bridle-chain connections. The hoisting rope is attached to the cage by a closed rope socket, pin-connected between two main steel drawplates. Two main chains connect the main drawplates with the two main cross beams on the cage. Two bridle chains are connected independent of the main chains and extend from a rope clamp above the rope socket to separate connections on the main cross beams of the cage. Cam-shaped safety catches with toothed surfaces are installed at the extremities of each jack shaft and are arranged so that when functioning they will grip the wooden cage guides. One safety catch on each jack shaft has a web cast integral with it; this web serves as a counterweight to assist the gripping action and also prevents the safety catch from overturning when the mechanism functions. The safety catches are kept out of contact with the guides when the cage is suspended on the hoisting rope.

A right-hand bell crank is attached rigidly at its center to one jack shaft; a left-hand bell crank is attached similarly to the other jack shaft. Each bell crank has an upper and a lower arm. A chain with a clevis at its lower end is attached to the upper arm of one bell crank, and the chain is attached by an eye bolt at its upper end to a small angle plate, which is riveted to one of the main drawplates. A second chain is attached to the upper arm of the other bell crank by a similar connection to the small angle plate. The lower arms of the two bell cranks are attached by clevises to a horizontal spring, which is in tension when the hoisting rope, and the two bell-crank connecting chains are in tension. If the hoisting rope breaks, tension is released from the bell-crank connecting chains, the tension spring contracts, and the safety catches turn toward the guides and grip them. The gripping action is assisted by the downward movement of the cage.

Tests for effectiveness of the safety catches are conducted near the surface landing without disconnecting either the hoisting rope, main chains, or bridle chains, and the hoisting shaft is not blocked. The workmen climb on top of the cage bonnet and clean the safety catches of any foreign material that might interfere with their operation. A workman uses a steel bar to force the lower arm of bell cranks outward; obviously, the upper arms turn inward. Wooden blocks were placed under the lower bell-crank arms to hold them in position. This operation further expanded the tension spring and gave slack in the chain connections to the upper arms. The chain connections to the upper arms were removed, and a link about 28 inches long and 5½ inches wide over-all, made of 1-inch round steel, was inserted over the two upper arms of the bell cranks. The wooden blocks were then removed, and the link retained the bell cranks in the position in which they had been held previously by the chains. The link has a crosspiece of 1-inch round steel welded to it near the center. A hemp rope was tied securely to the crosspiece of the link, and the other end of the hemp rope was tied to a substantial member in the

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head frame about 10 feet above the surface landing. The length of the hemp rope was such that about 20 feet of slack was in it after both ends were secured. The hoisting engineer was signaled to raise the test cage until the deck was about 4 feet above the surface landing. The cage was stopped, and a quick examination was made to see if everything was in readiness for the test. The engineer was signaled to lower the cage in the shaft. As the cage descended, the slack in the hemp rope was "taken up," the link was jerk away from the upper arms of the bell cranks, the tension spring contracted, and the safety catches functioned. The cage dropped about 12 inches after release of the safety catches, which gripped the guides and suspended the ca in the shaft. Considerable slack was observed in the hoisting rope, main chains, and bridle chains, indicative that none of these was supporting the cage. Examination of the safety catches and the position of the cage disclosed that all safety catches functioned. The hoisting engineer raised the cage, after which the safety catches were disengaged. The cage was stopped near the surface landing, and two workmen stepped onto the bonnet. A steel bar was used to turn the bell cranks, which, with the aid of wooden blocks, were forced into position to permit reconnection of the chains to the upper arms of the bell cranks. The chains were reconnected, the wooden blocks were removed, and the workmen descended from the cage.

A hoist in balance, utilizing two cages, is operated at this mine for hoisting men, supplies, and rock. The second cage was tested immediately after completion of the first cage test by following the same procedure, and similar results were obtained.

Lake Superior District[13]

Types of Safety Catches

The safety catches inspected are of the general type and the actuating mechanisms work on the general principle shown in figures 9, 10, and 11, whic were copied from drawings furnished by the National Iron Co. of Duluth, Minn. The dimensions in the figures vary, because drawings of three different cage were used to show the desired details. Four cast-steel cams, with steel pin inserted in the faces, are mounted on the ends of two substantial jackshafts that extend across the top of the cage. The cams are placed in pairs, the pairs being arranged to engage both sides of the cage guides when in the clo position and to clear the guides when open. In the design shown, the coiled springs, which close the catches by rotating them to contact the wooden cage guides, are mounted on the jackshafts. In other designs, the springs are mounted in a vertical position on the top of the cage and rotate the cams through levers attached to the jackshafts.

Some safety catches have been designed that have the teeth cast as an integral part of the cam. However, in all the tests witnessed and herein described, cams with steel pins inserted in the face were used.

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[13] Pearce, C. M., and Cash, F. E., Testing Safety Catches on Mine Cages, Lake Superior District: Bureau of Mines Inf. Circ. 7325, 1945, 12 pp

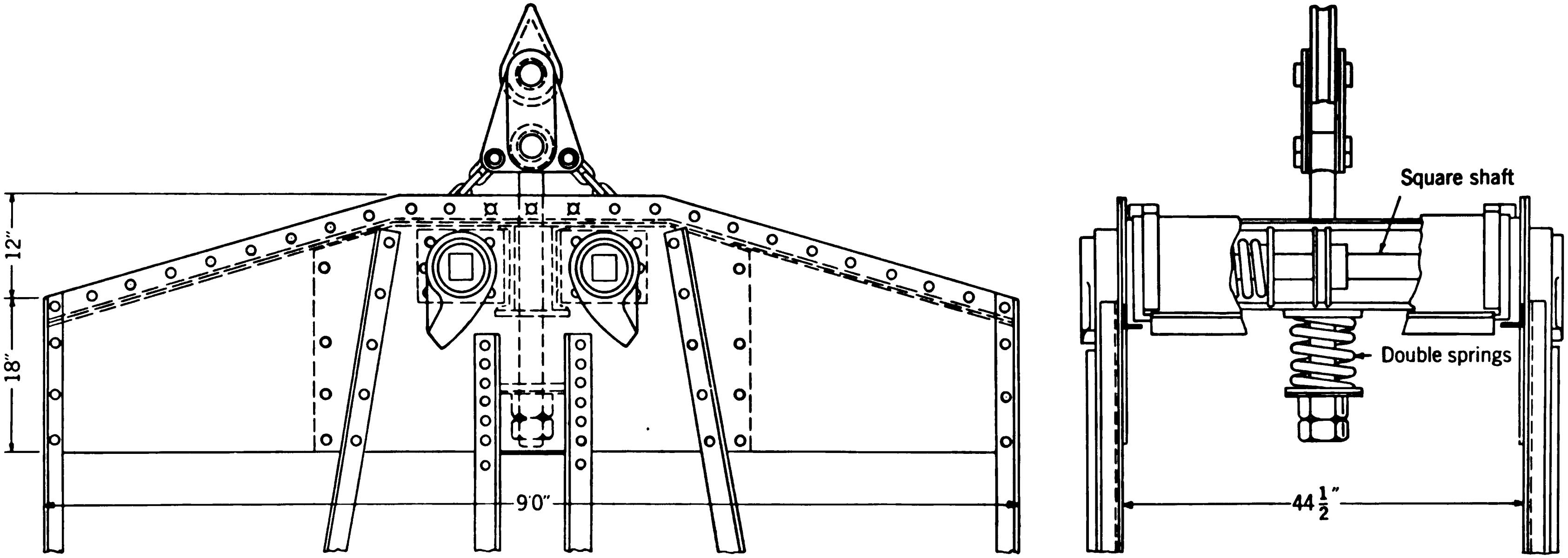


Figure 9. - Top of man cage showing safety catches.

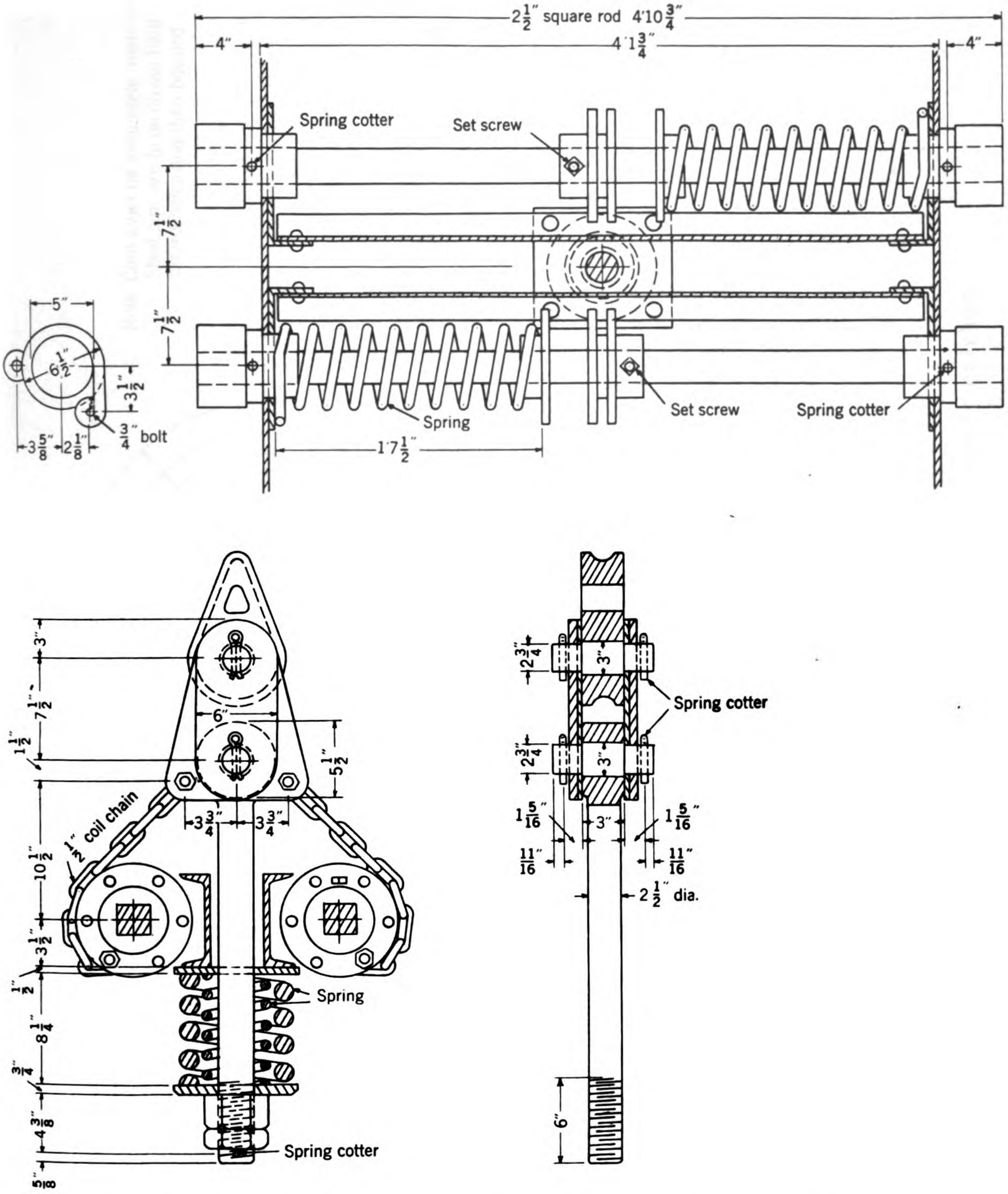
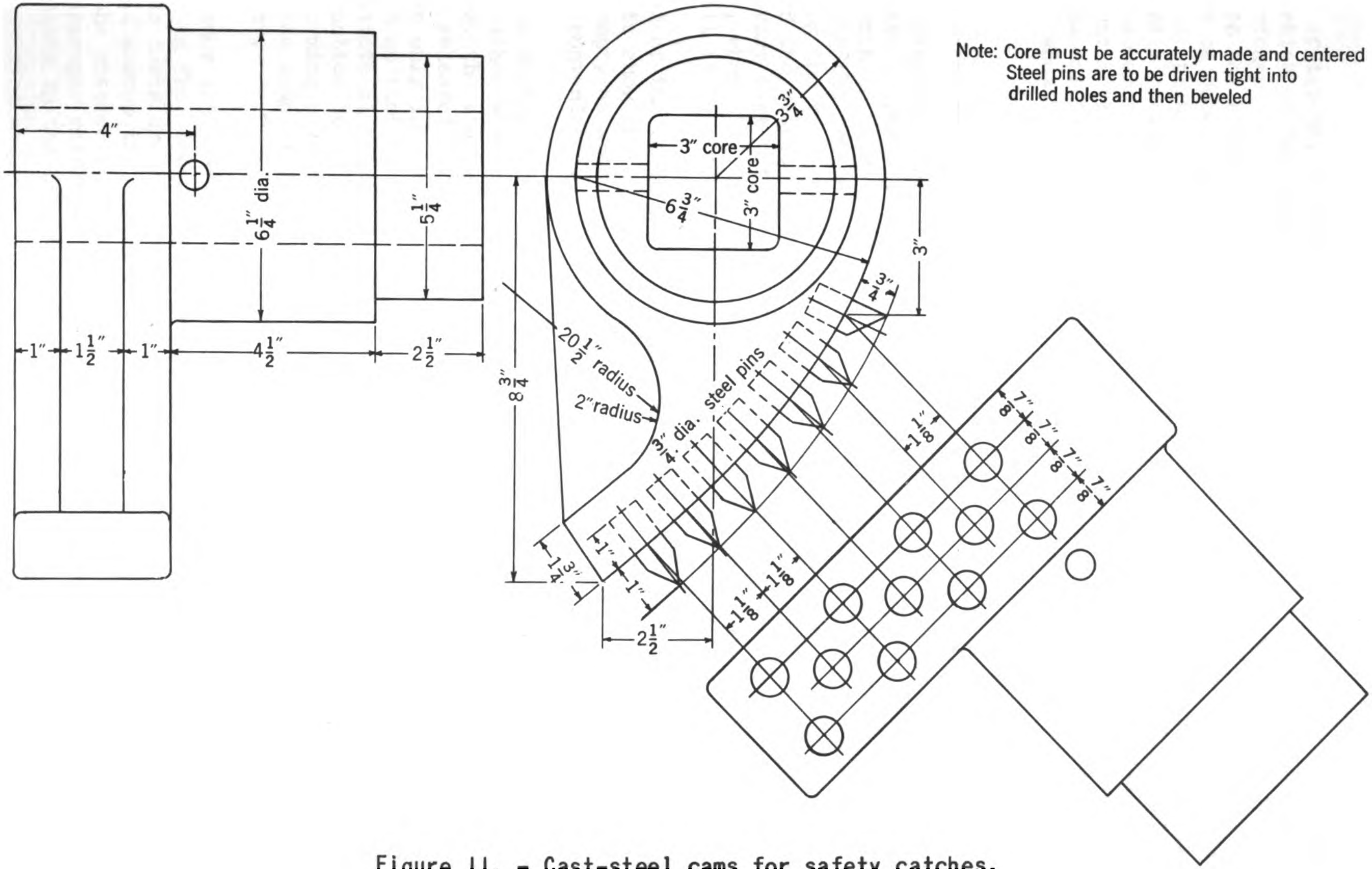


Figure 10. - Cage hanger and safety-catch assembly.



Note: Core must be accurately made and centered
Steel pins are to be driven tight into
drilled holes and then beveled

Figure 11. - Cast-steel cams for safety catches.

The efficiency of the various designs is not pertinent to this report, as the action of the cams was similar in all the tests. The cam-shaped safety catches are held open and clear of the wooden cage guides by the tension on the hoisting rope. If this tension is released through the cage being set on some firm support or through the failure of the hoisting rope, the coiled springs rotate the jackshafts, turning the cams toward the timber guides until contact is made and cams firmly grip the timber. Any further downward movement of the cage causes the cams to grip the timber guides more firmly, until they are forced into the timber and almost invariably stop the cage. The safety catches are released and returned to their normal operating position, when tension is reapplied to the rope by raising the cage with the hoist.

Methods of Testing

The general method of testing the safety catches is the same at all mines investigated. Periodic inspections range from cleaning the catch mechanisms once a month to a thorough daily inspection with the cage resting on chairs, and testing the action of the catch-actuating mechanism by releasing and reapplying the tension on the hoisting rope. A drop test, with a written report of the results achieved, is made every month. Methods of testing differ, but in every test the cage is suspended from some device attached to its drawbar, and, when the suspending device is released, the freed cage is allowed to drop until it is stopped and held by the safety catches.

Most of the tests are made with an empty cage. Many of the mine officials said tests show that the reaction of the safety catches is the same when the cage is empty as when it carries a dead load; therefore, the empty cage is used for convenience.

It is worthy of note that in seven of the thirteen tests observed, the safety catches were not disturbed before the test was made. In the other six instances, the cage was lowered onto rests, and the tension on the hoisting rope was released during the process of installing the testing device. At one mine, the only inspection is made during the monthly drop test, when the cage is rested on timbers at the collar of the shaft both before and after the test to facilitate cleaning and oiling of the safety-catch mechanism. As it is the usual practice to release the tension on the hoisting rope by pulling slack in it and forming a loop around the tripping device rather than by disconnecting it from the cage, this method is referred to in this report as the "slack-rope drop test".

Another interesting practice is the provision of short, easily replaceable sections in the wooden cage guides at the point where the cams engage in testing. The tests are conducted just above the collar of the shaft, and blocking is placed across the collar to prevent the cage from dropping down the shaft, should the catches fail. There have been occasional failures, but these were due to improper maintenance, such as allowing ice or other foreign material to accumlate in the actuating mechanism.

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Test of Safety Catches

Mine H. - Mine H has a daily production of approximately 2,200 long tons of iron ore, which is hoisted from a depth of 3,600 feet in two 9-ton-capacity skips operated in balance. One double-deck cage, balanced with a counterweight, is provided for the transportation of the 218 underground employees and mine supplies. Both the skip and cage hoists are equipped with Lilly controllers as protection against overspeed and overwind.

The cage is equipped with cam-type safety catches, which are normally held open by the tension on the hoisting rope. When the tension is released, the cams are rotated by springs, which force the teeth against the wooden cage guides. The safety catches are inspected daily by noting the action of the mechanism as the cage is placed on chairs at the collar of the shaft. They are tested each month by the slack-rope drop test.

When the safety catches are to be tested, the cage is hoisted into the headframe, the shaft opening is covered by steel fire doors, and two 6-inch steel H-beams are placed over the doors for greater strength. Two steel-rope slings are fastened to the hoisting rope, one about 4 feet and the other abo 20 feet above the cage. A 3/8-inch steel cable with 3/4-inch block and tackl attached is fastened to the upper sling to pull slack in the hoisting rope. A steel ring is provided on the lower sling for attaching the lower end of the tripping device, which is illustrated in figure 12. The upper end of the device is fastened to a 5/8-inch steel chain, which is attached to and supported by members of the steel headframe. When the tripping device is in place, the cage is lowered until its weight is supported by the tripping device. About 1½ feet of slack is then pulled in the hoisting rope, the tripping device is sprung, and the freed cage drops until the safety catches function. If the cage drops more than 3 inches, the safety catches are adjusted, and the test is repeated until the drop is 3 inches or less.

Mine I. - Mine I has three shafts ranging in depth from 2,700 to 3,200 feet; one is vertical, and the other two are inclined about 67 degrees. The output of 4,600 long tons of iron ore produced each day is hoisted in skips in the vertical shaft. All three shafts are equipped with cages, which are used for the transportation of supplies and the 470 underground employees. The hoists are equipped with Lilly controllers for protection against overspeed and overwind. The cages are equipped with cam-type safety catches, which are normally held open by the tension on the hoisting ropes. When the tension is released, the catches are rotated by springs in the actuating mechanism, and the teeth on the cams are forced against the wooden cage guides.

The safety catches are inspected daily by a mechanic, who rides on the bonnets of the cages as they are lowered onto the cage chairs at the collars of the shafts and watches the action of the mechanisms. Any imperfection is corrected without delay.

The safety catches are tested each month by the slack-rope drop tests. When a test is to be made, the cage is hoisted above the collar of the shaf

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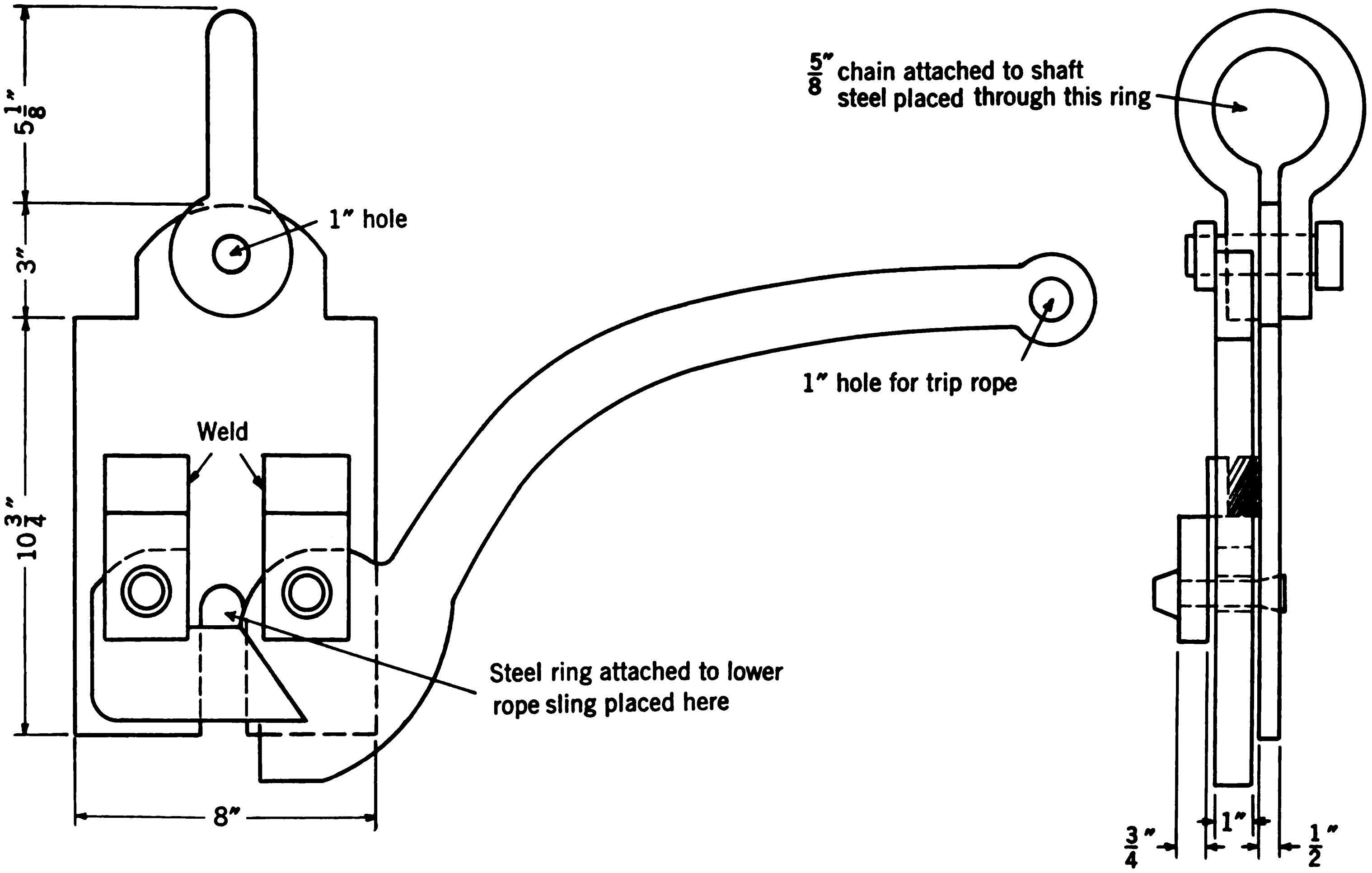
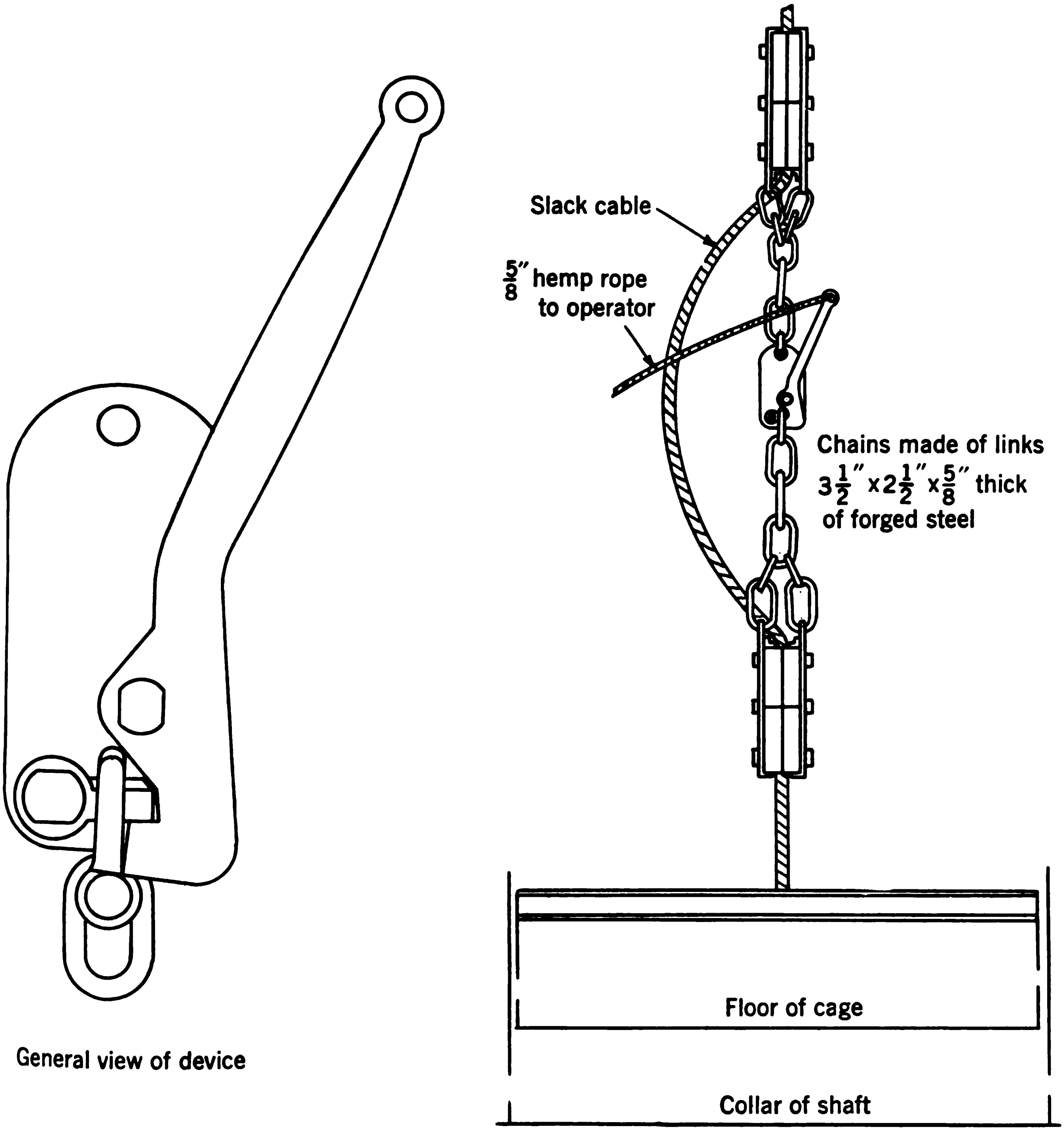

$5\frac{1}{8}''$
$3''$
$10\frac{3}{4}''$
$8''$
1" hole
Weld
Steel ring attached to lower rope sling placed here
1" hole for trip rope
$\frac{5}{8}''$ chain attached to shaft steel placed through this ring
$\frac{3}{4}''$
$1''$
$\frac{1}{2}''$

Figure 12. - Tripping device for testing safety catches - mine 4.


Slack cable
5/8" hemp rope to operator
Chains made of links 3 1/2" x 2 1/2" x 5/8" thick of forged steel
Floor of cage
Collar of shaft

General view of device

Figure 13. - General arrangement of device for testing safety catches - mine I.

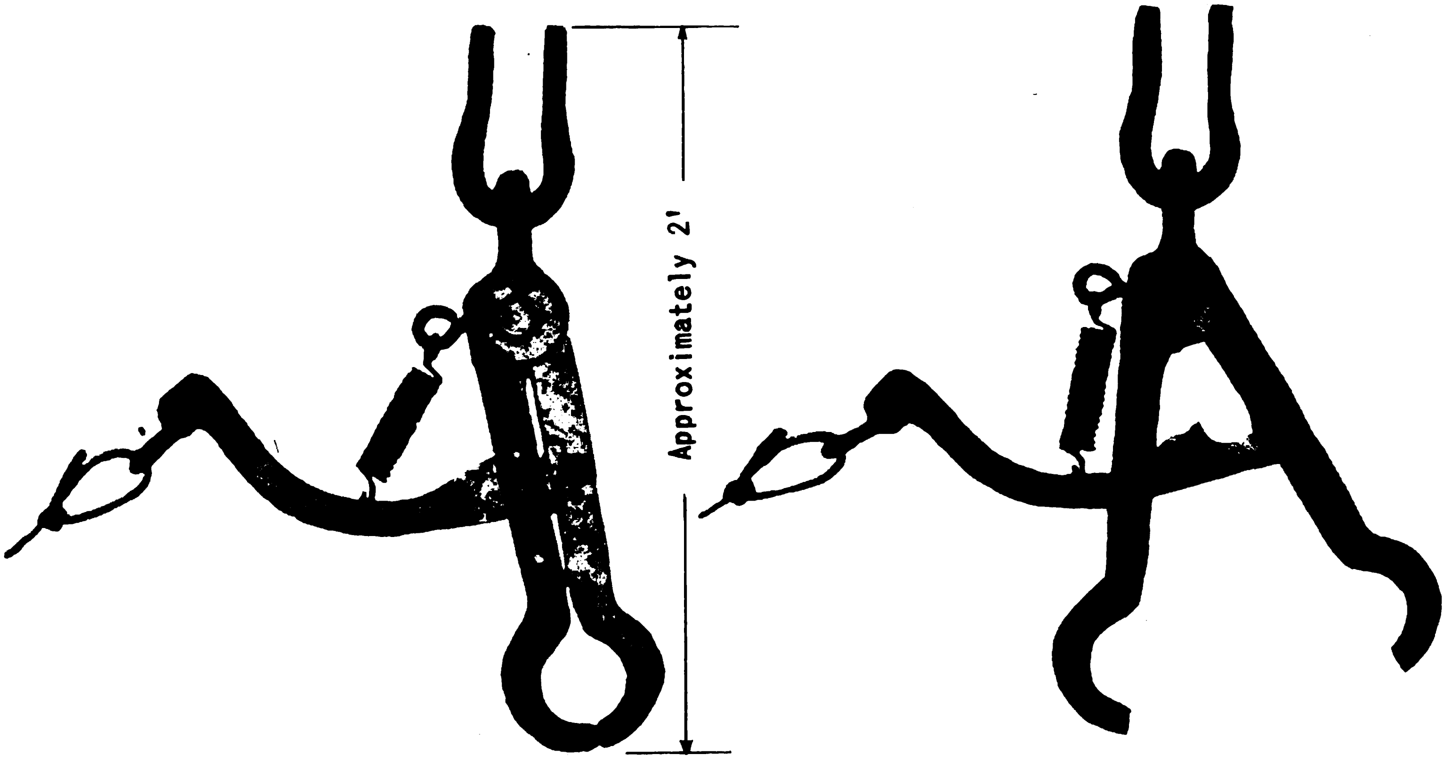


Figure 14. - Tripping device for testing safety catches - mine K.

two tiers of four 3- by 12-inch planks are placed across the shaft, one on each side, and the cage is lowered onto these planks. Two clamps that support the testing device (illustrated in fig. 13) are attached to the hoisting rope, one just above and the other about 30 feet above the cage; slack is pulled by means of a hand line attached to the upper clamp; and the lower chain of the testing device is attached to the tripping device, which is suspended from the upper clamp, forming a loop in the hoisting rope. The cage is then suspended from the testing device by hoisting it 1 to 4 feet above the blocking across the collar of the shaft. When arrangements have been completed, the tripping device is sprung, and the freed cage drops until it is stopped by the safety catches. If the drop exceeds 3½ inches, the safety catches are inspected and put in proper working order. The cage is spotted for each test, so that the cams of the safety catches will engage undamaged places on the removable sections of the wooden cage guides.

Mine J. - The 348-foot deep shaft at mine J is equipped with two skips and a cage. Daily production is about 1,000 long tons of iron ore, and 80 men are employed underground. The cage is unique in the Lake Superior district, as it is normally operated as an elevator by the skip rider. It can be operated in the usual manner by switching the control to the hoistman. Interlocking switches prevent simultaneous operation of the two controls.

The method of making the monthly drop test of the safety catches is similar to that used in other mines in the district, but the place where the test is made is unusual. When the drop test is to be made, the cage is hoiste into the headframe, a 12- by 12-inch timber is placed across the shaft at the collar, and the cage is lowered onto the timber. Boards are laid on the ground between the hoist house and the first idler stand, and enough slack is pulled in the hoisting rope to cause it to lie on the boards. Two steel plate with Crosby clips are fastened to the hoisting rope where it is lying on the boards, and the testing device is attached to these plates so that a 15-foot loop is formed in the rope. The hoist is then started, and the cage, supporte by the testing device, is raised about 10 feet above the 12- by 12-inch timber The testing device is sprung by means of a trigger and rope, and the cage, freed of support, drops until the safety catches function. The cage dropped less than 5 inches at the time the test was observed. The testing device was disconnected, splinters of wood were removed from the cams, and the cage was returned to its normal operation.

Mine K. - Production at mine K is about 2,000 long tons of iron ore a day, with 324 employees working underground. Four vertical shafts are in use, but only two, one about 2,200-feet and the other 1,200-feet deep, are used for the transportation of men and supplies. The hoists are equipped with automatic controllers for protection against overspeed and overwind. The ore is hoisted in skips, and men and supplies are transported in cages. The cages are equipped with safety catches, which are tested by dropping the cage a short distance once each month.

When the safety catches are to be tested, the cage is hoisted into the headframe, two 12- by 12-inch timbers are placed across the shaft at the collar, and the cage is lowered onto the timbers. The hoisting rope is disconnected from the cage, and a tripping device, shown in figure 14, is installe between it and the cage. The cage is hoisted a few feet above the timbers, the tripping device is sprung, and the freed cage falls until the safety catches function. According to report, the distance dropped ranges from 2 to 4 inches, depending on the condition of the wooden cage guides. About 20 minutes are required to make the test.

Mine L. - The four-compartment shaft at mine L is 700 feet deep; two compartments are used for the skips and are operated in balance, one compartment is the ladder and pipeway, and the fourth compartment is the cageway. Average daily production is 400 long tons of iron ore, and 30 men are employed underground. The hoists are equipped with Lilly controllers for protection against overwind. The cage is equipped with cam-type safety catches, which normally are held open and clear of the wooden cage guides by the tension on the hoisting rope. The safety catches are inspected every week, and they are tested by the slack-rope drop-test method every month.

When the safety catches are to be tested, the cage is hoisted into the head frame, and a piece of 12- by 12-inch timber is placed across the shaft at the collar. A piece of 6-inch steel pipe is placed across the cageway in the head frame above the cage; a chain is passed over the pipe and through a clevis attached to the drawbar of the cage, and the ends are fastened together by means of the tripping device illustrated in figure 15. The cage is lowered until it is suspended on the tripping device, and enough slack is pulled in the hoisting rope to insure that it will drop to the timber across the collar if the safety catches fail. The tripping device is then sprung, and the freed cage falls until the safety catches function. It is reported that the catches have never failed to stop the cage and that the maximum drop is 3½ inches. The test was made with a dead load on the cage, and the results were the same.

Mine M. - Mine M has two shafts, one vertical and one inclined, each about 3,000 feet deep. The vertical shaft is the production shaft and is equipped with two skips for hoisting ore and a cage for transporting men and supplies. The inclined shaft is used essentially for ventilation but is equipped with a cage, as it is an emergency outlet from the mine. Daily production is about 2,800 long tons of iron ore, and 339 men are employed underground. The cage in the hoisting shaft will carry a maximum load of 90 men when both decks are loaded.

The two skips are operated in balance, and the cage is balanced with a counterweight. Each unit is handled with a single-drum hoist, which is safeguarded with a Lilly controller for protection against overspeed and overwind. The cages are equipped with cam-type safety catches, which are normally held open and clear of the wooden cage guides by the tension on the hoisting rope. The safety devices are inspected weekly and are tested each month by the slack-rope drop-test method.

Testing equipment is permanently installed in the head frame of the hoisting shaft, and a clevis is installed on the cage to facilitate the test. When the cage is to be tested, it is hoisted into the head frame, three 12- by 12-inch timbers are placed across the shaft at the collar, and a chain is installed between the tripping device (fig. 16) and the clevis on the cage.

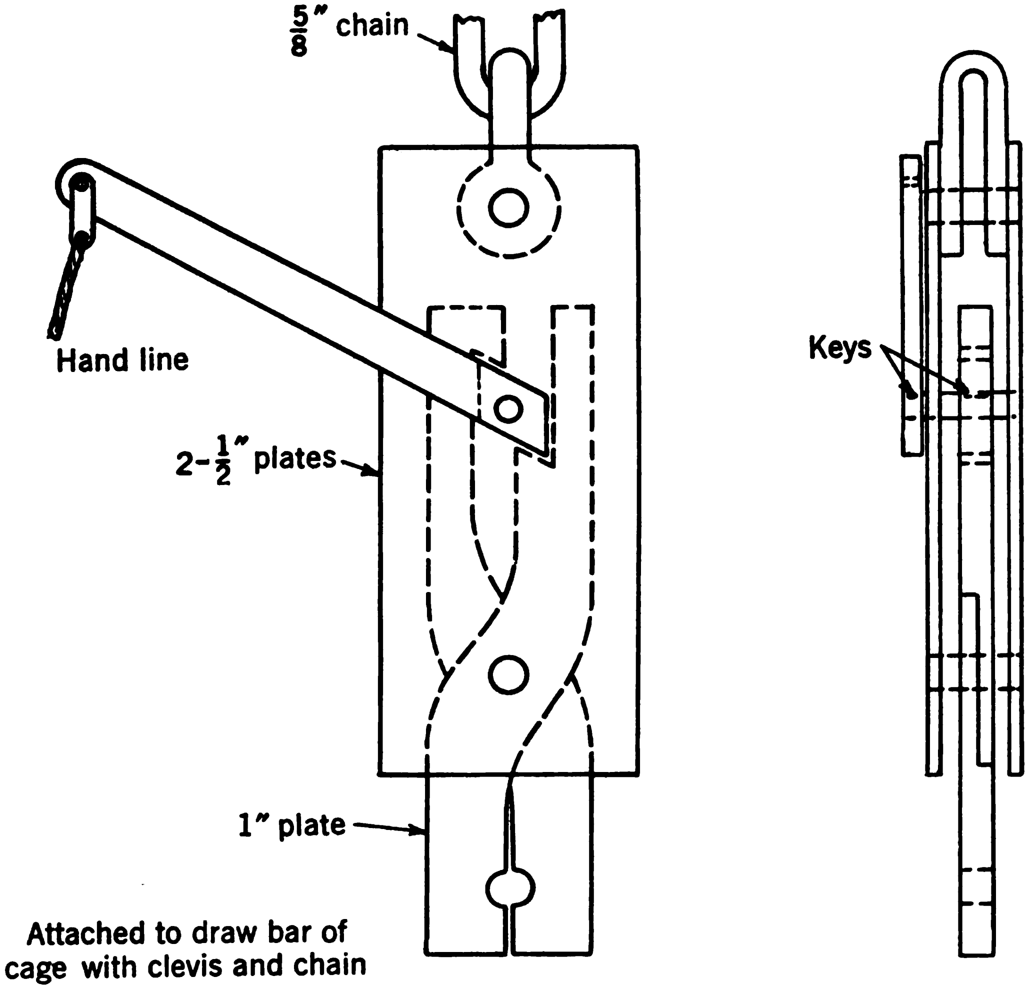


Figure 15. - Tripping device for testing safety catches - mine L.

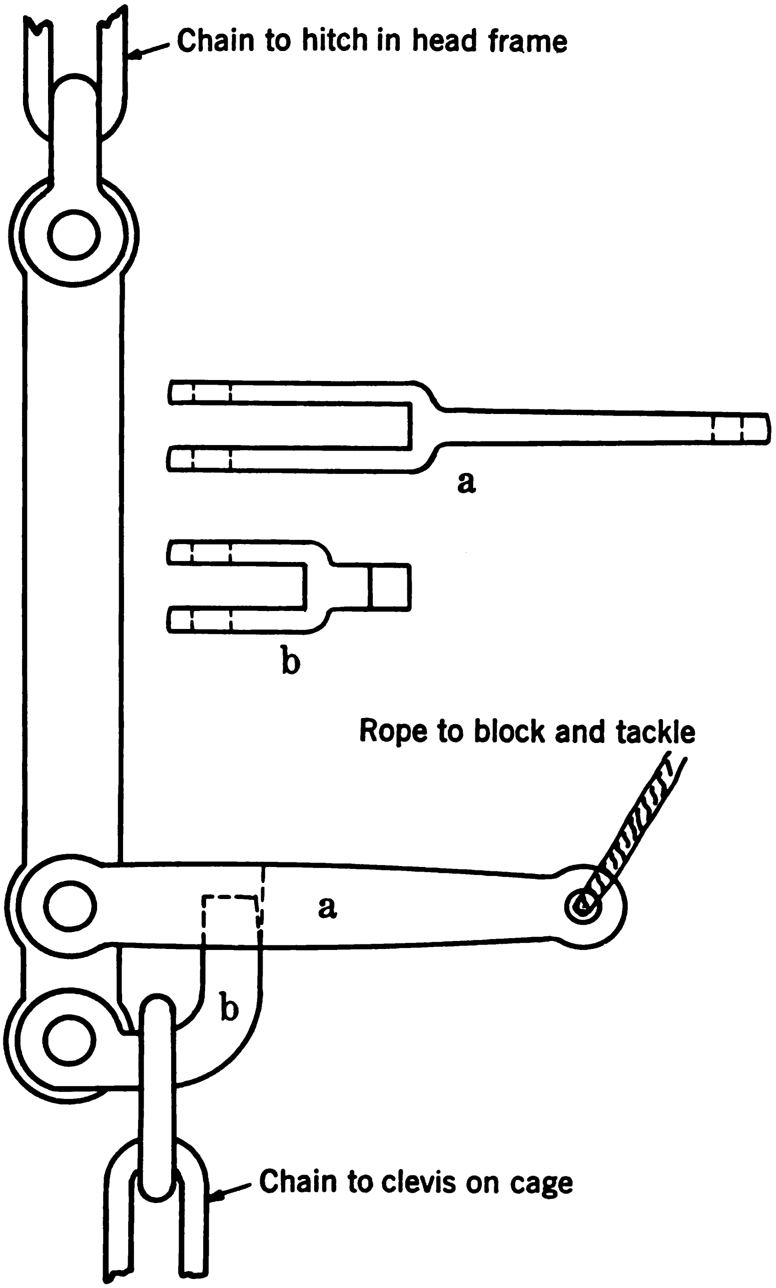


Figure 16. - Tripping device for testing safety catches - mine M.

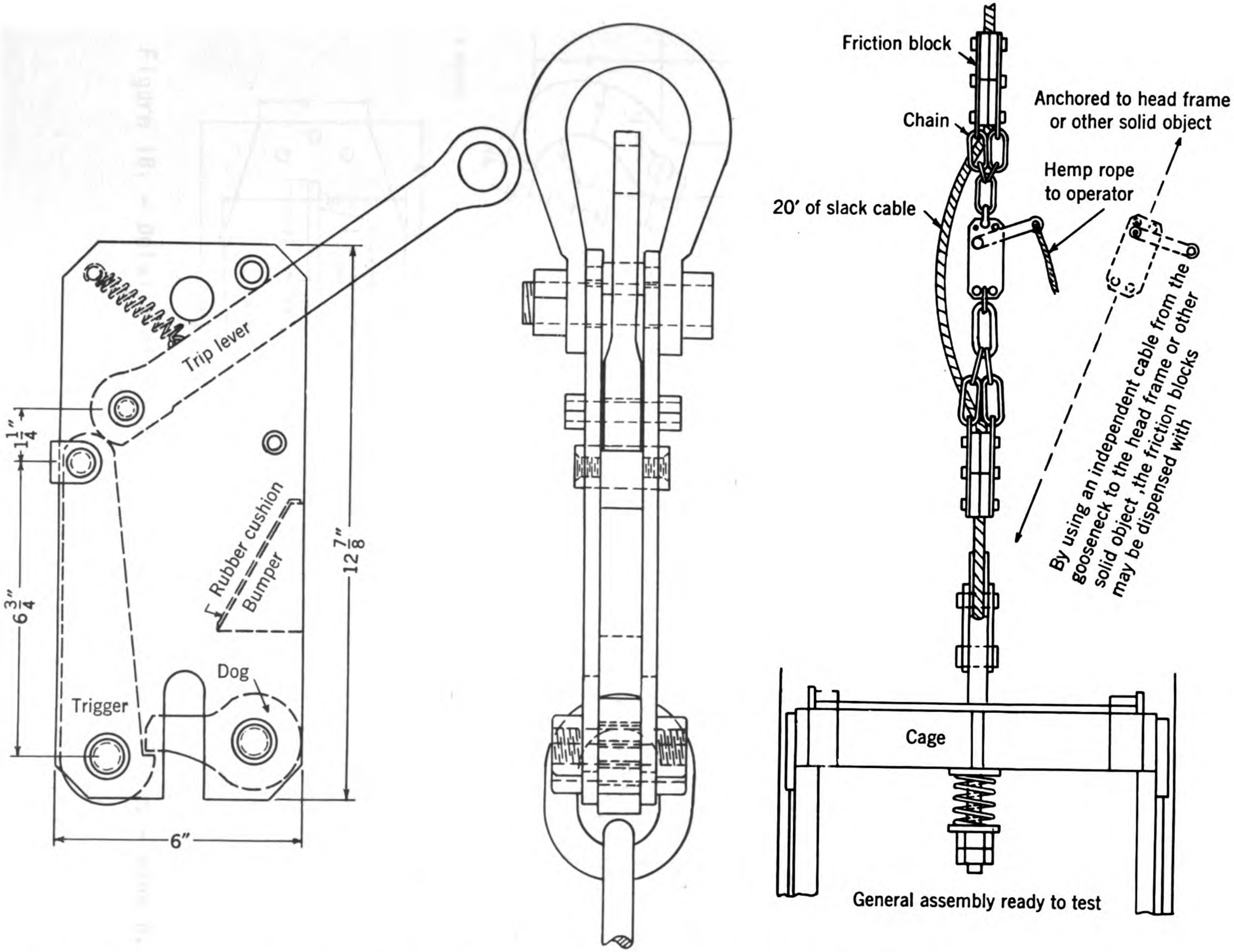

Trip lever
Rubber cushion
Bumper
Dog
Trigger
1¼"
6¾"
12⅞"
6"
Friction block
Chain
20' of slack cable
Anchored to head frame or other solid object
Hemp rope to operator
By using an independent cable from the gooseneck to the head frame or other solid object, the friction blocks may be dispensed with
Cage
General assembly ready to test

Figure 17. - General arrangements and details of device for testing safety catches - mine M.

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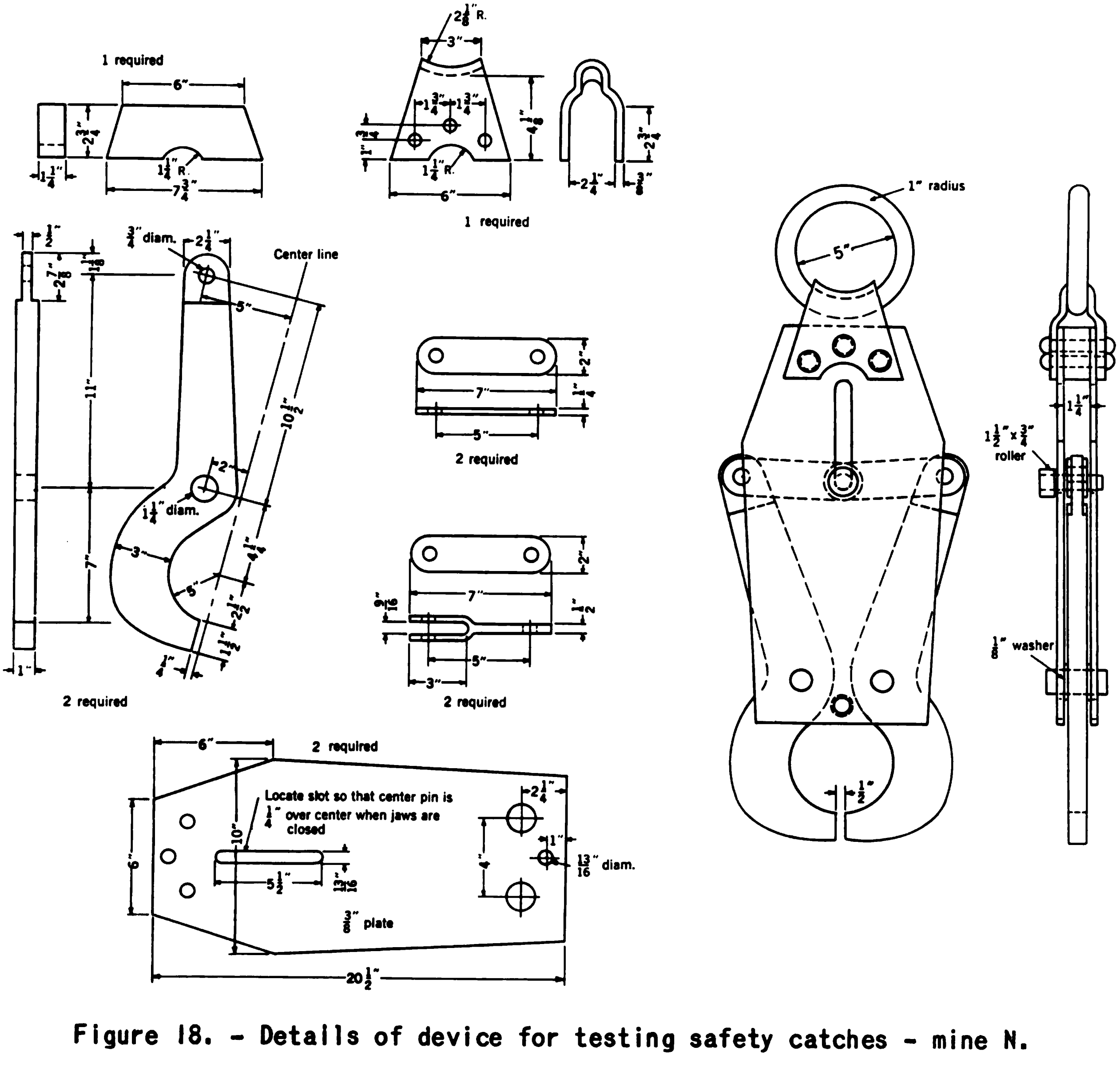

Figure 18. - Details of device for testing safety catches - mine N.

The cage is then lowered until it is supported by the testing device, and enough slack is taken in the hoisting rope to insure that the cage will drop to the 12- by 12-inch timbers if the safety catches fail. When these arrangements have been completed, the tripping device is sprung by means of a hand line, which is passed through a set of pulley blocks, and the freed cage drops until the safety catches function. The chain used for this test has seven special links for attachment to the hook of the tripping device, so that seven tests may be made, with the safety catches engaging in a different place in each test for each change of the renewable sections of the wooden cage guides.

The same general procedure is followed when testing the safety catches on the cage at the ventilation shaft, but the tripping device used (fig. 17) is sprung easily with a hand line.

Mine N. - The shaft at mine N is about 1,900 feet deep. Eighty men are employed underground, and an output of about 700 long tons of iron ore is produced daily. A cage is used to transport men and supplies.

When the safety catches are to be tested, the cage is hoisted into the head frame and two 12- by 12-inch timbers are placed across the shaft at the collar. A testing device in the head frame is swung out into the cageway and is attached to the top of the cage. The cage is lowered until it is suspended from the testing device, and slack is taken in the hoisting rope. When arrangements are complete, the tripping device (fig. 18) is sprung by means of a rope attached to the toggle joint, and the freed cage drops until the safety catches function.

A NEW TYPE OF SKIP GUIDE SHOE

The Wright-Hargrave gold mine at Kirkland Lake, Ontario, has been using pneumatic skip guide shoes instead of steel shoes in the ore-hoisting shafts for several years, and it is claimed that travel has been made smoother and maintenance costs have been reduced appreciably by the new installation.

One shaft has four compartments, two of which are skipways 4 feet 6 inches square, and the shaft depth is 4,000 feet. There are 30 levels and 9 loading pockets. The 4-ton skips are hoisted at a speed of 1,450 feet a minute. The shaft guides are of Douglas fir and Australian kaari wood and are 3-3/4 by 5-3/4 inches in section. The second shaft is an underground shaft or winze having a maximum hoisting depth of 2,500 feet. Two of the four compartments are skipways 4 feet 8 inches by 4 feet 6 inches in dimension. There are 16 levels with one permanent and several temporary loading pockets. The hoisting speed for ore is 1,200 feet a minute. The shaft guides are Douglas fir 4-3/4 by 5-3/4 inches in section. The wooden guides were subjected to considerable wear when the steel skip shoes were in service, and the steel shoes required frequent replacement.

A substitute arrangement for the steel skip shoes was installed on each skip assembly and consisted of 12 rubber-tired wheels, six at the top and six

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at the bottom of the assembly. At both the top and bottom of the assembly, one tire pressed against each side of the shaft guide, and the third tire, placed at right angles to the other two tires, was in contact with the front of the guide.

The wheel assembly consisted of a chrome nickel-steel axle and a ball-bearing rim on which is mounted a 250-4 four-ply tire. Each axle has a 7/8- by 2-inch threaded extension machined eccentrically and provides the means of attaching the wheel to the skip assembly and for adjusting the pressure of the tire against the shaft guide. The axle can be rotated so as to provi a movement of 5/16-inch to compensate for wear.

The rubber tires are inflated to 40 pounds pressure, and they are reported to be in good condition after 3,248 hours of use in one shaft and 2,640 hours in the second shaft. Formerly, two-ply tires were used, but these were found to be too light and were replaced with the present 4-ply tires.

The advantages claimed for this equipment are:

1. Travel of skips in the shaft is smooth and virtually noise-free.

2. Wooden shaft guides are kept in clean condition.

3. Very little tire wear has been noted.

4. Time required for shaft-guide and skip repairs has been reduced to a minimum.

5. The eccentric axle enables the operators to adjust the fit of the pneumatic guide shoes against the wooden shaft guides speedily and easily.[14]

EXAMPLES OF FALLING-CAGE ACCIDENTS

Paymaster Consolidated Mines

The falling-cage accident at the Paymaster Consolidated Mines, Ltd., was investigated very thoroughly by the Ontario Department of Mines and by a committee of engineers appointed by the Minister of Mines of the Province of Ontario. The official report of the accident is shown as the Appendix in Miners Circular 61, Safe Practices in Mine Hoisting, published by the Bureau of Mines. The following account of the accident has been abstracted from the official report:

> The hoisting rope on a double-deck cage lowering 16 men at the No. 5 shaft of Paymaster Consolidated Mines broke at 7:55 a.m., February 2, 1945. The safety dogs engaged the guides immediately, but they were torn out. They worked ineffectively, as the cage fell to the bottom of the shaft, a distance of over 1,700 feet.

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[14] Engineering & Mining Journal, vol. 147, No. 4, April 1946, p. 106.

The cage stopped in the spill pocket about 19 feet above the shaft bottom. The impact resulted in instant death to all but two men. Only one man was reached while still alive, and he was unconscious when removed. He died enroute to the South Porcupine General Hospital.

The Paymaster shaft extends from the surface to a depth of 2,685 feet; there are three compartments. Both hoisting compartments are flush, tight-lined. The guides are B. C. fir dressed exactly to 5 inches wide and 4 inches thick. Maintenance consisted of changing guides when the face was reduced to a width of 4½ inches. All of the guides in the cage compartment from 1,214 feet below the collar to the bottom were new, creosote-treated, B. C. fir guides. These guides had been in service only a month and a half and showed no wear.

The shaft conveyances consisted of two skips and a double-deck cage. The double-deck cage was used in the center compartment in balance with the skip in the west compartment to hoist and lower the shifts and to handle material. It was interchangeable with the skip, and when muck was hoisted, it was replaced by a skip in the center compartment. The skips weigh 3,838 pounds each, and the maximum load carried in the skips was 6,000 pounds. The double-deck cage weighed 4,205 pounds. The hoisting rope weighed 1.8 pounds per foot, and the maximum weight of the rope was 4,889 pounds. The distance from the sheave to the lip of the loading pocket was 2,716 feet. The safety factor, based upon a total load of 14,969 pounds, was 6.8, but the load actually carried was less than this. The permissible man load, based upon 85 percent of maximum load of 14,969 pounds, was 12,700 pounds. Subtracting the weight of the cage and weight of rope, the permissible weight of men who might be carried was 3,363 pounds. The combined weight of the 16 men who were killed was 2,365 pounds.

The safety dogs on the cage were the standard design supplied with the cage; the dogs were 4 inches wide, the biting width of the face teeth was 2-3/16 inches. The teeth, five in number, were designed to bite successively deeper into 5-inch guides up to a maximum of 13/16-inch on each side of the guide when fully engaged. The lower sides of the first four dog teeth were cut to meet the guides at right angles, the last tooth was cut to turn slightly beyond a right angle to exert a compressive force on the guides when fully set. When fully set to engage a 5-inch guide to a depth of 13/16 inch, the dogs were prevented from rotating further by a shoulder on the draw bar that came in contact with the top of the cage after the draw bar had dropped 3½ inches. At the beginning of the movement, the force of the springs pulling the draw bar down was supposed to be 3,000 pounds. At the end of the movement, the springs were supposed to exert 1,000 pounds pressure.

The hoisting rope was manufactured in February 1941 and placed in service on August 5, 1942. It was held in storage in a dry shed for 17 months. The rope was flattened lang-lay rope made of 6 strands of 27 wires, 12 over 12 over 3. The strands were wound over a Java core. The manufacturer's breaking-strength rating of the rope was 51 tons.

Using the manufacturer's breaking-strength rating of 102,000 pounds for the rope and a suspended load of 14,969 pounds, the static safety factor was 6.81. Based upon the actual breaking strength obtained on tests on February 4, 1943, September 13, 1943, March 2, 1944, and September 18, 1944, when breaking strengths of 100,700, 100,000, 101,000, and 98,700 pounds, respectively, were obtained, the safety factors were 6.72, 6.68, 6.75, and 6.60. In all the tests, the lubrication of the core was found to be good and no unusual corrosion was evident.

The No. 5 shaft hoist is a double-drum hoist having a rated hoisting capacity of 11,450 pounds, maximum unbalanced load, or 15,650 pounds balanced load at a speed of 1,200 feet per minute. Both drums are 60 inches in diameter and have 36-inch faces grooved for 1-inch rope. The first winding takes 33 laps of rope; successive windings take 34 laps. The hoist is equipped with a Model "D" Lilly controller.

The No. 5 shaft is operated on three shifts; the graveyard shift hoists muck. Before commencing to load the 8 a. m. shift, the empty cage was run through the shaft and the Lilly controls were tested. Two cageloads of men were lowered to the bottom levels, and the third load was descending when the accident occurred; the third load had been run to the 1,050 level.

The hoisting engineer states that he was "feeling" his brakes and that the cage was at about the 900 level when the rope broke just outside the hoist-room and the broken end fell back through the wall. He immediately applied his brakes and brought the ascending skip to a stop; the engineer is very positive the brakes were not applied before the rope broke. When the hoist was stopped, there was about 25 feet of rope on the floor and about 11 laps of rope on the fourth layer of the drum, all of which had recoiled and loosened.

A group of miners in the shaft house heard the trailing end of the rope thrashing the roof and headframe as it was drawn down the shaft.

The rope failed at a point 1,130 feet from the cage, leaving 1,844 feet of rope on the hoist. The dogs contacted the guides first at 950.4 feet below the shaft collar, but they were either bounced out or were whipped out by the trailing rope; the teeth of the dogs probably filled with wood at this point. After the first bite, the dogs began to score deeper, and from the top of the new guides to the bottom they cut uniformly to a combined depth o 7/16 inch on each guide. The width of the cuts averaged 2-1/8 inches on one guide and 1½ inches on the other. It has been suggested that the uniformity of the depth of cut was caused by the dogs being prevented from rotating further and biting deeper by the linkage.

The committee of engineers investigating the accident concluded the causes of the accident were as follows:

1. Unsuspected and extreme corrosion of the hoisting rope was the primary cause of the loss of life that resulted from the fall of a mine cage in No. 5 shaft of the Paymaster Consolidated Mines on February 2, 1945.

2. The flat-strand rope as new was of a type and quality recognized as standard and in accordance with what had been considered good practice in the mining camps of Ontario. It is, however, more vulnerable to corrosion than round strand rope.

3. The diameter of the hoisting drum was and remains too small in proportion to the diameter of the rope. Severe crushing and unstranding stresses will exist when as many as five layers of rope are wrapped around the drum. This occurs when the cage in this installation is at the top of the shaft. The head sheave is also too small in size.

4. Failure of the safety dogs to arrest the fall of the cage after the rope had broken was the secondary cause of the loss of life.

5. While before the accident the type of dog that was used at Paymaster was generally accepted in the mining camps of Ontario as one of the standard types and was widely used in them, the Committee finds that it was faulty. The teeth were too shallow, thus easily clogging with wood spoil and causing the dog to slide over the face of the timber guide without retarding value.

6. Proper functioning of the dogs was, in the view of the Committee, prevented in some measure by a faulty setting, which prevented opposing dogs on opposite faces of a guide to engage the guide deeply enough. Even a correct setting might have been offset by the lodging of a piece of rock under the shelf angles attached to the drawbar about 3½ inches above the roof of the cage. The Committee regards this as an objectionable detail.

7. The Committee is of the opinion that the 1,130 feet of trailing rope between the break and the cage probably had an important bearing on the failure of the dogs to engage the guides effectively after they had first taken hold.

Western Lead-Zinc Mine in 1936

A mine cage at a western lead-zinc mine fell 900 feet and killed 10 men in October 1936.

Immediately prior to the accident, 5 men, including the cage attendant, got on to the lower deck of the 2-deck cage at the 3,450-foot level. They were hoisted to the 3,050-foot level in order to complete loading men on both decks. The cage attendant permitted 6 men to get on the lower deck, making a total of 10 men on the cage. The cage doors were then closed and fastened. The hoist engineer was signaled to lower the upper deck flush with the shaft-station floor, and this was done. The attendant unfastened the lock at the top of the upper cage door and was in the act of raising the bar extending across the cage door when the hoisting rope broke about 1,200 feet above the cage. According to the attendant, the cage appeared to fall, bounce, and then fall again. As the rope went by, it was whipping from side to side in the cage compartment. The cage fell about 900 feet to the bulkhead below, where it was smashed and badly twisted.

The cage was used exclusively for hoisting and lowering men and was run in one of the three compartments of the main shaft.

The flat hoisting rope was 3/8-inch thick and 4½ inches wide and was made up of 13 primary strands 3/8 inch in diameter. Each of the primary strands consisted of 4 secondary strands of 7 wires each, a total of 364 wires. The strands were purchased from a wire-rope manufacturer, and the rope was made in the company shops by sewing the 13 strands together with 16-gage wire. The rope weighed 2.83 pounds per linear foot, and the breaking strength was 72.8 tons.

The hoisting rope was attached to the cage by shackling about 6 feet of the rope bent back upon itself after passing around the thimble. Two safety ropes about 4 feet long extended from the crosshead and were bolted firmly to the hoisting rope immediately above one of the shackles.

The safety catches were fitted with pick points that would dig into the face of the shaft guides rather than on the side of the guide when the tension on the hoisting rope was released. The safety catches were operated by springs, which forced the catches against the guides. The safety catches on the cage were inspected weekly and tested periodically.

The hoisting rope was inspected weekly, and cotton waste was held against the moving rope to detect projecting broken wires. The rope was treated with a "tarry" compound, which was forced in between the strands; this made it difficult to determine by visual inspection the actual condition of the rope, as the broken wires might be flattened against the rope and not discerned by the tests used at this mine.

The cage weighed 3,600 pounds, the 10 men weighed 1,600 pounds, and 1,200 feet of rope weighed 3,396 pounds, a total weight of 8,596 pounds. The breaking strength of a new rope was 72.8 tons and the factor of safety was about 16 to 1, but obviously the figures did not represent actual conditions, or the rope would not have broken. The rope was placed in service January 17, 1936, and broke on October 6, 1936.

The guides showed no indication that the safety catches contacted them. If the safety catches failed to operate, it was probably due to the trailing-rope effect of the 1,200 feet of the hoisting rope between the break and the cage, which kept enough tension on the coil springs to prevent their action. There is also the possibility that the guides were worn and the safety catches could not contact them.

The break was rather clean, as evidenced by the fact that the loose wires or fraying did not extend more than 2 feet from the break. Some corrosion was evident, but most of the wires retained their ductility, as indicated by the broken ends, which were drawn out to needlelike points at the break.

Western Mine in 1944

A falling-cage accident occurred in a western mine in 1944. Ore was being handled, and no one was injured in the accident.

A single-drum hoist at the collar of a raise operated a 2-deck cage in the hoisting compartment; ore and waste were lowered in mine cars of 20 cubic feet capacity to a haulage level from three intermediate levels above. The cage was used, also, to hoist and lower men in 10-man trips.

The hoisting rope was 7/8-inch diameter and 6 by 19 construction. The rope passed over a 48-inch-diameter sheave placed 50 feet above the collar of the raise, making a 45° angle. The rope was attached to the cage through a thimble; a 4-foot section of the rope was clamped around the thimble with 10 wire-rope clamps.

The lower part of the raise was wet, and the hoisting rope was exposed to dripping corrosive water; the break occurred in the lower part of the rope.

The cage weighed 3,000 pounds; the two loaded mine cars weighed 6,600 pounds, and the 1,000 feet of rope weighed 1,200 pounds, a total weight on the rope of 5.4 tons. The breaking strength of the rope, by manufacturer's specifications, was 32.2 tons, giving an estimated factor of safety of 5.96 when the rope was new.

The hoisting rope was installed on November 17, 1942, and broke on May 24, 1944, after operating an estimated 3,120 hours.

Two loaded mine cars were trammed on to the deck of the cage at the 600-foot level; the cage was raised from the shaft chairs and lowered on power. When the cage was 70 feet below the 600-foot level, the hoisting rope broke and the cage dropped into the sump at the foot of the shaft. The hoisting engineer stated that the rope broke without warning; there was no indication of a "hung" cage.

Inspection of the shaft guides at the point of the rope failure revealed that the safety catches had functioned ineffectively. A deep groove was worn in the guides for 36 feet, until the space between the teeth of the safety dogs filled with wood, and from there down the safety dogs slipped on the guides, merely scarring them. The guides were not displaced, nor were any raise timbers disturbed. The company officials reported that the safety catches were inspected periodically and that the hoisting rope was inspected on the day preceding the accident.

Inspection of the hoisting rope at the point of failure showed a normal break due to excessive load upon a rope weakened by corrosion and wear of the individual wires. The wear on the crown wires was estimated to amount to approximately 47 percent of the original section. The hemp core of the rope was completely dry, and the underside of each crown wire was corroded badly; the corrosion amounted to nearly half of the original diameter of the wires. The interior wires were badly corroded and very brittle.

The hoist drum and sheave, the angle of the rope over the sheave, the fleet angle, the hoisting speed and load on the rope, all were within safe and normal mine practice. The wear on the rope was not sufficient to indicate a dangerous weakening of the rope; however, internal corrosion had weakened the rope to a dangerous degree, and this could not be determined by visual inspection. The accident could have happened with 10 men on the cage instead of 2 loaded mine cars.

SUMMARY AND CONCLUSION

Safety in mine hoisting is given considerable attention at most shaft mines. The cages and skips are kept in good mechanical condition, the hoisting rope is inspected and changed, and the safety catches are tested periodically to be sure that they function correctly. However, hoisting ropes continue to break, and usually the cage or skip falls to the bottom of the shaft in spite of the existing safety devices.

The committee investigating the falling-cage accident at the Paymaster Consolidated Mines in Ontario reported 47 accidents of this type; overwinding caused 23.4 percent and corrosion of the hoisting rope caused 14.9 percent of the total.

Lack of a positive safety device that will stop a falling cage or skip every time under all conditions of use makes it of utmost importance to do everything feasible to prevent the hoisting rope from breaking.

Investigations have shown that the point at which a hoisting rope is most likely to break has not been established. Tests have shown that the weakest section of 41 out of 44 hoisting ropes investigated was not at or near the socket end, and in only 15 percent of the tests was the weakest point found in the lowest 10 percent of the rope length between the sheave and the socket when the cage was at the bottom of the shaft.

Internal corrosion of wire ropes is one of the principal causes of hoisting-rope failure. Hoisting ropes having a high resistance to corrosion should be used. Anything that tends to promote corrosion is more dangerous than something that produces surface wear, as surface wear usually can be detected with little or no difficulty.

Shaft guides are often torn loose or broken when the safety catches engage them. Longleaf yellow pine generally is regarded as the best wood for shaft guides in the United States; in Canada, British Columbia fir is preferred.

Steel guides are used in some shafts, particularly where heavy loads and high hoisting speeds are required.

Trailing ropes (the part of a broken rope attached to the falling cage or skip) exert a tremendous influence upon the performance of the safety catches. A long trailing rope may prevent the safety dogs or catches from engaging the guides, or it may release the safety catches after they have engaged.

Ontario statistics recording the performance of safety dogs or catches reveal that in 10 out of 33 instances on record the safety catches were not effective in stopping the cage. The safety catches were effective in only 64 percent of the accidents that were fully recorded.

Experimental and existing safety catches were tested by various mining companies in Ontario in cooperation with the Department of Mines, and of 116 tests reported, the safety dogs failed to act satisfactorily in 12.1 percent. The tests were conducted generally with the cage loaded, and the safety catches were caused to function when the velocity of the falling cage ranged between 850 and 2,000 feet per minute; in the tests in which the dogs did not stop the cage, the velocities ranged between 900 and 1,630 feet a minute. The speed of the falling cage appears to have less influence on the effectiveness of safety catches than the trailing rope has.

The methods of testing safety catches at some American bituminous coal mines and the mines in the Lake Superior mining district are described, and some of the devices are illustrated. It appears to be the usual practice in the United States to test the efficiency of the cage safety catches, using an empty cage in place of a loaded one, and to gage the effectiveness of the safety catch by the distance required to stop the cage from the moment it starts falling.

The results of the tests of safety catches made in Ontario mines and a study of the various falling-cage accidents that have been reported fully appear to indicate that none of the safety catches on mine cages or skips can be depended on to stop and suspend a falling cage or skip under all conditions of use. It is believed that the present methods of testing mine-cage safety catches do not represent the performance of the safety catches if the hoisting rope fails when the cage is loaded, particularly if the cage is descending.

It is believed that safety catches on mine cages should be tested while the cage is loaded with weights that will approximate the maximum cage load. The cage should be allowed a free fall of several feet before the safety catches are caused to function. The results of tests under these conditions will approximate more nearly the performance of the safety catches under actual conditions than the usual test methods. The tests, however, will not represent what will happen if a long trailing rope is attached to the cage as a result of rope failure.

It is strongly recommended that the attention of manufacturers be directed to the development of mine-cage and skip safety devices that will always function quickly and safely, and will counteract the influence of the trailing rope. It is also recommended that some dependable, practical method be devised to determine with reasonable accuracy when a hoisting rope should be replaced to avoid an accident that would require safety dogs to function.